Risk perception of heavy metal contaminated soil between exposure and emotional concern

from the case to the experimental design

Abhandlung
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Content

1. Introduction

1.1. The Idea of this work

The term 'risk' is certainly one the terms which plays a very prominent role in our lives. The majority of people think that they are more at risk than previous generations, although the expected lifetime is significantly longer (Dake, 1992). Why is it that aeroplane crashes and terror attacks are leading to enormous public attention and to political consequences, when the risk of dying in a car accident is very much higher (Gigerenzer, 2004)?

Risk is always dependent on the reference system. For a young sportsman for example, 10 kilograms is easy to lift, for an old lady 10 kilograms is very heavy. Or sometimes, when one is totally absorbed in something, an hour passes very quickly; another time, when one forces oneself to do something, one has perhaps the subjective feeling that the hour is endless. In the same way people differ in the way they perceive a risk. Moreover, there is no objective physical measure for risk. Risk is a subjective construct and thus highly dependent on differences in the individual perception and on the cultural or social framing, e.g., lay persons and experts do differ in the way they perceive and judge a risk.

The over all goal of this work was to get closer to the psychological processes which are involved when people are dealing with risks. On the one hand, my work should be based on previous empirical findings and classical methodical approaches, on the other hand, these classical approaches should be critically analysed and developed, and also newer approaches should be considered. The focus should be no more on the characteristics describing the risk source, but on the way these characteristics are processed. At the end of this project, a model of individual risk perception, which is based on the results, should have been developed.

Risk perception is always bedded in a risk situation. The way individuals deal with a risk is always the result of an interaction of psychological and situation elements. This work analysed the real-life risk situation, as it was given in the case of Dornach. Dornach is a village near Basel, where the soil is widely contaminated with heavy-metals (copper, zinc, lead). It is one of the two places in Switzerland with the highest contamination and, of course, there is a certain risk potential.

This project was part of a larger project, in which several scientists from different disciplines analysed the case of Dornach. Although there are also a lot of interesting results from the other projects, I refer to them only selectively. For further information see appendix.

1.2. Theoretical Background

1.2.1. Historical roots and change of the risk notion

The term ‘risk’ was used for the first time in the Italian commercial language of the 19th century (Rammstedt, 1992). The etymological roots point to the Greek language, whereby it can mean both root and also cliff: it means those cliffs around which a merchant ship should sail. The closer the ship sails around the cliffs, the faster it reaches the harbour, which certainly represents a gain. If the ship goes too near the cliff and is wrecked, then there is a loss. Up until the 19th century, the time of the developing industrial society, risk was understood as opportunity costs for the creation of prosperity and wealth (Dake, 1992). Blaise Pascal (1623-1662) was the first to describe how to measure probability. The risk theory of Laplace (1816) especially had a crucial influence on the risk conception and on the emerging insurance industry. The simple formula 'risk = harm x probability' suggests a predictability and thus a controllability of the risk. Until the end of the 60's of the 20th century, a very limited risk concept was predominant. An extension and a differentiation of the term ‘risk’ seemed to be unnecessary due to a nearly unrestricted trust in the possibilities of science and technology.

Since the 70's the term ‘risk’ has gained substantially in meaning and also in complexity. On the one hand, the obvious negative consequences of technology were certainly a reason for this development. On the other hand, the conception of the human was changing from a full rationality to a bounded rationality (Simon, 1957). It became clear that humans can not be fully rational like a computer, the cognitive capacity is limited, human beings make mistakes and they use simple heuristics, which are different to normative solutions (Kahneman & Tversky, 1982). This change of the conception of the human could also affect the unlimited trust in science and technology and therefore the concept of the risk.

The risk concept is quite popular in today's society. Some authors (e.g., Ulrich Beck, 1986) call the post-modern society even the risk society. Of course, disasters such as Tschernobyl and September 11, or diseases like AIDS and SARS are attracting more attention to the risk topic. Luhmann (1991, 1993) noted that there is an historical shift from danger to risks. In a pre-industrial time people were confronted with dangers like thunderstorms or flood, where they could not do very much against it, they only could hope or pray that it will not happen to them. In the modern or post-modern time people are confronted with a lot of different risks. In contrast to dangers, risks are man-made and it always has a decision of an actor behind. Renn (1993) explains the topicality of risk in modern societies with the following four factors: 1. The increase of knowledge of causal chains let events be accept any longer as fate-given. In consequence, people do have a growing demand of predicting and controlling possible negative consequences. 2. While natural dangers were reduced, civilisation risks were increasing. Since civilisation risks are not natural but man-made, risks have to be legitimated. 3. The catastrophic potential increased due to the evolution of technology requires collective decision-making processes. Even if the probability of a damage is very small, in case of damage to a lot of people, probably all the society could be affected. 4. The individual marginal utility of economic prosperity is diminishing (in the western industrial nations) in favour of the marginal utility of general health, clean environment and psychological well being.

In conclusion, the change of the meaning of risk and the risk conceptions, and their dependency on cultural change and historical events make clear that risk is a subjective construct and not an objective given fact (Douglas & Wildavsky, 1993).

1.2.2. Defining risk

It is not that easy to come up with a clear definition of risk. Of course, it can be seen as the product of probability and harm. But it could also be defined by different logarithms. A risk function could focus on the probability of loss, the size of the loss, the maximal loss, a product of probability and loss, the variance of the consequences, the semi-variance of all possible losses, and so on (Scholz & Tietje, 2002). Some experts even use a second order probability. This is the probability, in the sense of uncertainty, in how far the proper probability is correct. But a definition of risk only based on a formula might be not sufficient. Different scientific disciplines and different industries work with different conceptualisations of risk. Risk is a widely used, disputed and multifaceted concept. The concept might include qualitative aspects, e.g. economic, psychological, social, cultural, environmental, or philosophical aspects. One might want, for example, that only the negative consequences are defined as a risk, or one may also include the favourable aspects in the risk definition. The former is called pure risk and the latter is called speculative risk (Fishburn, 1982; Brachinger & Weber 1997). However, it is easier to give a definition of the risk situation than of risk itself. A basic or minimal risk situation in the sense of a decision structure has always at least two alternatives (see Figure 1). At least one alternative has at least two outcomes. It is not sure what the outcome will be by choosing the alternative, but one might know the probability (Scholz & Tietje, 2002: p. 176). Thereby, one outcome is a subjective loss in comparison to the other outcome ($v(E_{2,1}) <> v(E_{2,2})$. Furthermore, one of the outcomes of A_2 has a higher value than the outcome of A_1 and the other outcome has a lower value than the status quo ($v(E_{2,1}) > v(E_1)$ and $v(E_{2,2}) < v(E_1)$).

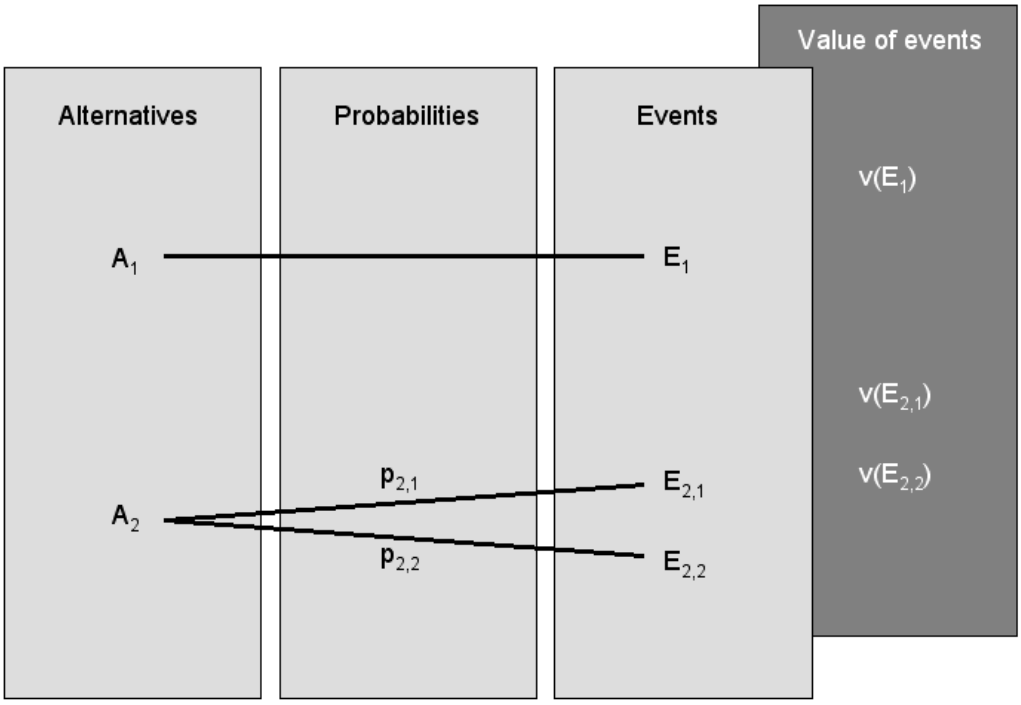

Figure 1. Elementary risk situation. (Source: Scholz & Tietje, 2002; adapted)

1.2.3. Lay persons risk judgements

Lay persons and experts do consider different aspects in their risk perception. Some difficulties can be experienced in judging probabilities (Hansson, 1989; Gigerenzer & Hoffrage, 1995; Scholz, 1987). There are also cultural differences in the perception of probabilities (Philips & Wright, 1977). In general, people tend to underestimate high probabilities and overestimate low probabilities, as is postulated in the Prospect Theory (Kahmeman & Tversky, 1979, 1992).

The Prospect Theory also postulates an individual reference point, which determines if an outcome is perceived as a loss or as a gain. Depending on the cognitive framing of the situation consequences are either perceived as a gain or as a loss. Thereby, the gain function is different from the loss function. The utility function (with objective gain and loss as x-axis and subjective utility as y-axis) is concave for gains and convex for losses. Whereas in the area of small gains a probable additional gain has more value than a secure lower gain, in the area of high gains a probable additional gain has less value than a secure but lower gain. Differences in the area of small losses are subjectively high evaluated. In the area of high losses additional losses do play a less and less important role. Thereby, a loss has a subjective more importance than an equal sized gain. The prospect theory as an example of a subjective utility theory is a descriptive theory, which is based on empirical findings. It shows that people act differently from the normative solutions. Nevertheless, the fact that it is possible to describe decision-making behaviour with a mathematical function proves that people use some rules and do not behave irrationally.

People also use systematically some heuristics or biases in their decisions, which are also in conflict with the normative solution and are insofar not rational. The availability heuristic and the base rate fallacy are examples of such biases (Kahneman & Tversky, 1973). For example, following an aeroplane crash, the risk of travelling by aeroplane is rated higher because the negative event is still in mind and available. People regularly ignore the base rate in their judgements, which contradicts the Bayes theorem (Scholz, 1987). Changing the information format from a probability to a frequency format can reduce even the base-rate fallacy (Gigerenzer & Hoffrage, 1995; Scholz, 1987). It is advantageous to present the information with visualised frequencies of possible events rather than stating abstract probabilities. However, in some cases, for example when the decision has to be made within a short time and not all the necessary information is available, heuristics can be a quite good strategy (Gigerenzer, 1997). From an evolutionary point of view, people act in an adaptive way.

Besides the quantitative description of risk as a product of probability and harm, lay people also use qualitative characteristics such as voluntariness, controllability, or catastrophic potential in their risk perception and judgements (Slovic et al., 1980; Slovic et al., 1985). A risk source is perceived as being less risky if people are exposed to it voluntarily, feeling they have control over the risk, or they do not see the possibility of a catastrophe. In a factor-analytical approach - also called the psychometric paradigm in risk perception research - these qualitative characteristics could be reduced to the two main factors "dread risk" and "unknown risk" (Slovic et al. 1980; Slovic, 1987; Slovic, 1992; see Figure 2). Slovic et al. (1980) found a third factor exposure, which could not be replicated in other studies.

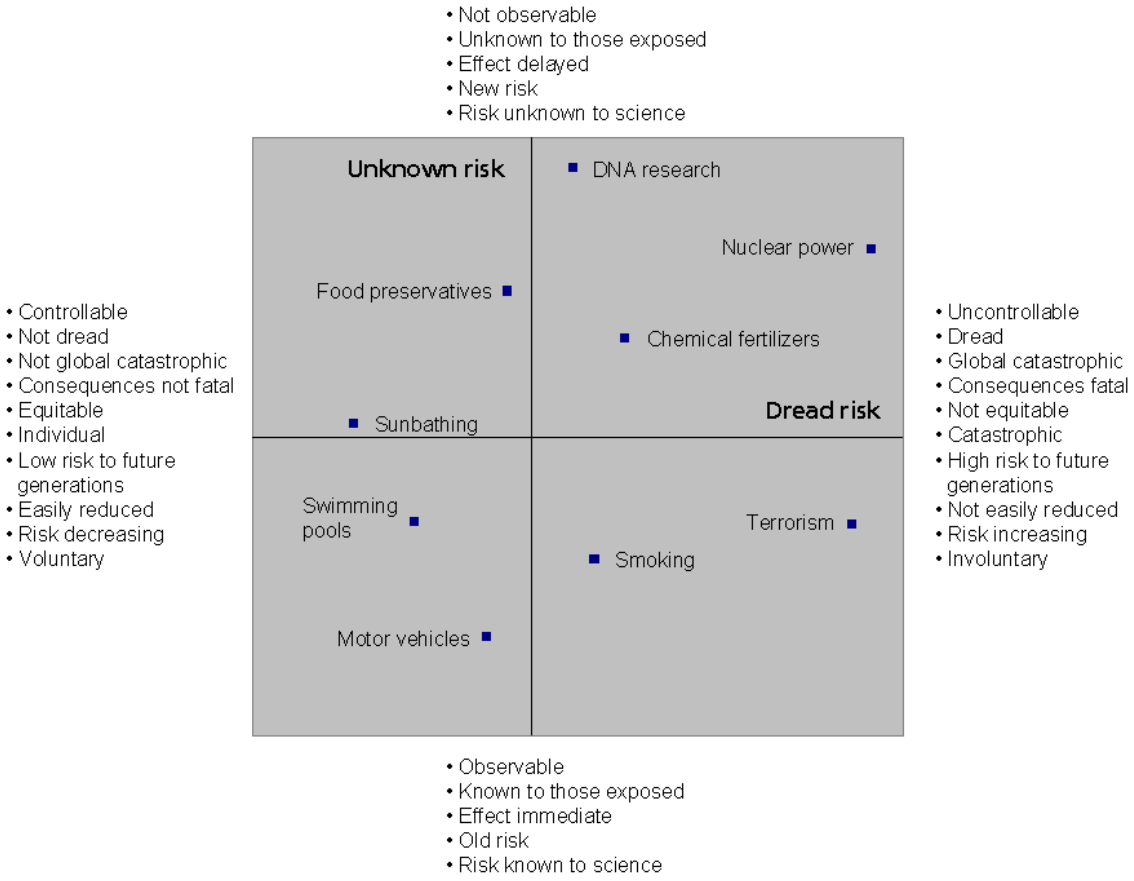

Figure 2. Locations of hazards on factor 1 (dread risk) and factor 2 (unknown risk). The factor space derived from the interrelationships of 18 characteristics. (Source: Slovic, Fischhoff & Lichtenstein, 1980; adapted).

On the social level there are processes which determine the social impact of a risk. Even small risks (judged small by experts) can have a strong social impact. According to the theory of the social amplification of risk (Kasperson et al., 1988) individual or group reactions may lead to ripple effects which may affect even the whole society. One example is the case of "Three Mile Island". Although the problem of the nuclear reactor did not result in any casualties, the case became more and more important and led to consequences which were timely, spatial, and thematically far away from the case "Three Mile Island" (Jungermann & Slovic, 1993).

1.3. The goal of the dissertation project and how to get there

On the one hand, we wanted to describe the risk perception in the case of Dornach, and on the other hand, we wanted to get closer to the individual processes in risk perception in general. In a first questionnaire based study (part 2), we assessed the risk perception in Dornach on a rather descriptive level. We used a factor analysis similar to those in the psychometric paradigm to see where the risk of heavy-metal contaminated soil is located.

As described in the theoretical background, the psychometric paradigm is a very prominent approach in the psychological risk perception research (Slovic, 1992). Nevertheless, this factoranalytic approach has its weak points. One problem is the Aggregation of data over participants (Marris et al., 1997; Lanngford et al, 1999). In the classical analysis only the mean of all participant for characterising a risk source is integrated in the factor analysis. Thus, it describes rather the risk sources than the risk perception process, and individual differences are excluded. Because we want to clarify the individual risk structure, we compared the classical with an individual solution (part 3).

But the psychometric paradigm has also another more fundamental problem. The following short invented story will explain what this problem is about:

> O. Hurry conducted an investigation. He wanted to find out how a car functions. First, he made a list of the main components of a car and how they could be described. He then composed a questionnaire with it. The questionnaire was filled out by all of his students, and then he did a factor analysis with the results. The first factor consisted of wheels, spare tires, crankshaft and steering wheel. Hurry labelled this factor wheeliness. A second factor contains headlights, fog lights, and the oil emergency lamp. This factor was called lightiness. A third factor consisted of gas, brake, coupler, air conditioner, and radio button. This is labelled as manipulation. A fourth factor is called Instruments, whereby the revolution counter, the tachometer and even the clock highly loaded on this factor. Hurry did not admit more then 4 factors. He then published his results, and ever-since, Hurry is always cited when the functionality of a car is discussed. However, do the factors wheeliness, lightiness, manipulation, and instruments really help us to understand the functionality of a car?

As you can see this method can reduce your universe of variables in a view dimension but doesn't tell you anything about the underlying psychological processes, functionality or goals. Even Thurstone (1947), a father of the factor analysis told that this procedure only supplies a very first map of the field.

Thus, the psychometric approach was very helpful (Slovic et al., 1980, 1985; Slovic, 1987, 1992) to show that there are other qualitative and rather subjective components besides probability and harm, which affect the risk perception. But if we want to know more about the individual processes involved in peoples risk judgements, we have to go in another direction. And it is not simply drifting from an aggregate to an individual analysis within the psychometric paradigm (Marris et al., 1997; Lanngford et al, 1999). On the way to find a general risk function, you have to evaluate the agents space of risk cognition (Scholz & Tietje, 2002). The space of risk cognition includes numerical representations of the risk situation (numbers of statistics like frequencies or subjective probabilities), semantic aspects such as voluntarity or dread, episodic risk knowledge, and prototypes (pictorial representations). This is just a summery of different aspects people take into consideration when they deal with risk. More interesting is the question, which of these elements play which role and how information is integrated. Which mode of thinking (Scholz, 1987), intuitive versus analytic, leads to which consequences on the risk judgement. And in how far the cognitive space of risk cognition is influenced or interacts with the emotional state or dispositions of the agent? In the terms of Scholz (1987) emotional

involvement has an influence on the goal system, the evaluative structure, the decision filter and the cognitive framing.

Thus, in study 3 and 4 (part 4 and 5), the focus was on individual processes involved in risk perception. Based on theoretical considerations, empirical findings in literature, and the own experiences with the case of Dornach (the first interview-based study), the following variables were included: Emotional concern, actual knowledge, self-estimated knowledge, desire for additional information, the use of dissonance-reducing heuristics, and thoughts about sustainability. In study 4 also the mode of thinking (intuitive versus analytic) was included.

The role of emotions in risk perception and decision-making became more important preliminary in the last decade (Finucane et al., 2000; Schwarzer, 2000; Lerner & Keltner, 2000; Lopes, 1987; MacDaniels, 1995; Karger & Wiedemann, 1998; Baron et al., 2000; Rundmo, 2002; Sjöberg, 1998; MacGregor, 1991). Thereby, one main result is that feelings of worry and fear increases the perceived risk. But emotions can also affect the information processing (Bohner et al., 1994; Trumbo, 1999) or appear in different steps of the decision process (Schwarzer, 2000). In addition, not only worry or fear have an influence on risk perception, also other emotions can show an influence (Lerner & Keltner, 2000). In our studies (3 and 4), we were particularly interested in what way emotional concern ("emotionale Betroffenheit") is related to exposure ("objektive Betroffenheit").

The transfer of knowledge is crucial in risk communication. To test the influence of the knowledge on the perceived risk, we assessed the actual knowledge participants in Dornach had about the soil contamination problem (e.g., the type of heavy metals, the path of danger). We also assessed the self-estimated knowledge, and the desire for further information. The level and the interrelation of the latter variable would be interesting in the risk communication context. The self-estimated knowledge could have a stronger influence on the risk perception than the actual knowledge (Baird, 1986).

In the first study, which was an interview-like survey, we were very often confronted with some weak arguments. These arguments seemed to play an important role in the risk perception. People probably used them to reduce their bad feelings about the problem. One example of such a heuristic was that the more frequent appearance of snails indicates a decrease of the risk. This is from a natural science view totally illogical. Thus, we collected the most frequent of these arguments, which we labelled dissonance-reducing heuristics, and included this concept in study 3 and 4.

Because the risk resulting from heavy-metal soil contamination depends on the degree to which one is exposed, exposure was a central variable in our studies. It was the independent variable in the two quasi-experimental designs in Dornach (study 1 and 3) and in the experimental design of the study 4. In the psychometric paradigm (e.g., Slovic et al., 1980) or with regard to the 'not in my backyard-effect (Marks & Von Winterfeldt, 1984), personal exposure increases the perceived risk. However, this influence may change with a long-term exposition, as it is the case of Dornach.

Whereas the surveys of study 1 and 3 could give a good picture of the real-life case of Dornach, the relevant variables could be tested free of break-down effects in the Microworld 'Dornhausen' I programmed for study 4. Of course, both methods have their advantages and disadvantages. Hence, using both for the same topic may be advantageous.

2. Risk Perception of Heavy Metal Soil Contamination and Attitudes toward Decontamination Strategies

Olaf Weber, Roland W. Scholz, Renate Bühlmann and Dirk Grasmück (2001)

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Abstract

Contaminated soils are a very common environmental risk all over the world. One major source of risk is heavy metal soil contamination caused by industrial emissions. In this quasi-experimental study we investigated the perception of these risks by exposed and non-exposed people, their attitudes towards bioremediation methods using hyperaccumulating plants and the influence of long term aspects of sustainability on the acceptance of bioremediation methods. Major findings were that people living in a contaminated area perceived the risk of the heavy metal soil contamination as higher than the general risk of contamination. Second, we could show by a factor analysis that the factors dread, control and catastrophic potential were relevant for the perception and valuation of low dose environmental risks like the contamination of the investigated area. In addition, a cluster analysis showed that the risk of heavy metal soil contamination was perceived similar to that of oil contamination, the ozone hole, preservatives and genetic technology. It was perceived indifferently regarding dread. Its uncontrollability was estimated as medium and its catastrophic potential as low. Third, exposed and non-exposed participants preferred bioremediation methods to classical methods using excavation and chemical treatment of the soil, because they perceived the environmental and esthetical performance of the bioremediation as important criteria. Last but not least, sustainability or precautionary issues, like the prevention of harm for future generations, were highly correlated with the acceptance of the use of bioremediation methods on the people's residential area.

Key words: Risk perception, environmental risk, heavy metal contamination, decontamination, sustainability

2.1. Introduction

How do people living on a site contaminated by heavy metals perceive the risk of this contamination in comparison to non-exposed people and to different kinds of risk? Are these exposed people in favor for a new sound decontamination method? Do sustainability or precautionary criteria play a role in the acceptance of different decontamination methods? We wanted to analyze these questions about the risk perception of heavy metal soil contamination and attitudes toward decontamination strategies by this study. It is embedded in an interdisciplinary project that has the goal to find decontamination methods, which will be valued in an integrated way regarding multiple criteria. This integrative evaluation will be done from an ecological, technical, economical and socio-psychological perspective because the risk perception of residents of the contaminated area and the acceptance of decontamination methods are important criteria for an integrated evaluation of decontamination measures. The data and results of the following study will also be integrated as decision support in a multicriteria decision model[5] to evaluate decontamination strategies.

2.1.1. Contaminated Soil

Contaminated soils are a very common environmental problem all over the world. There aremany heavily contaminated areas in nearly every country. One major kind of contamination is caused by heavy metals. This contamination has its source mainly from emissions of metal and steel processing plants. However, the European countries - with the exception of Eastern Europe - are not as affected by heavy concentrations of contamination as some countries in transition or some parts of the U.S.. Nevertheless, there are some areas in Switzerland, where the contamination could cause a risk to people's health. One of these sites is situated in the northwestern part of Switzerland. There the soil is contaminated especially with cadmium, zinc and copper passing the threshold value of .1mg/kg[1]. The contamination was caused by the emissions of a metal plant. Comparative studies showed that this concentration of cadmium causes health risks in a long-term exposure scenario[2-4]. A number of studies found that soil ingestion of children, long lasting consumption of food grown on the contaminated soil, and grazing of sheep were the most critical paths of pollution[4].

In 1993, first experiments with hyperaccumulating plants, which possibly could be used to decrease heavy metal contamination in these "low contaminated" areas, started. Because these experiments were successful, scientists started to look for practical solutions to extract heavy metals from soil by phytoextraction using plants like willow or tobacco.

2.1.2. Research questions

We developed a questionnaire with the participation of representatives of the contaminated area. With this questionnaire we investigated the following four main topics:

1. We wanted to analyze if and how the risk perception of heavy metal soil contamination is influenced by exposure. For this purpose we distinguished between exposed and non-exposed people and their perception of the risk on their residential area, the general contamination risk in Switzerland, and the risk for oneself and for other people. Following a number of former studies, people being exposed to risks of soil contamination should show a higher level of concern, which leads to a more

sensitive risk perception by residents of a contaminated area than by non-exposed residents[6-10].

2. As a second topic we analyzed similarities and differences in the perception of heavy metal soil contamination and other types of risks using multivariate methods.
3. We investigated the acceptance of different decontamination strategies, including bioremediation methods. These new methods were not often used in practice to date. Thus, information about the willingness to accept such new methods is one important aspect of a multicriteria evaluation of decontamination strategies.
4. Last but not least we analyzed, the impact of sustainability and precautionary criteria on the perception of the risk of heavy metal soil contamination and the acceptance of different decontamination strategies.

2.2. Method

2.2.1. Procedure

Participants who were exposed to an environmental risk (heavy metal soil contamination) as well as those who were not exposed filled out a questionnaire, while one of the project staff was present to help in case of questions. We informed the participants by mail that they and their city had been chosen at random. Representatives of the project group and the administration of the city signed the letter. In order not to prime the perceptions in any way, we gave no hints that the contamination of their place of residence was the main topic of the study. Nevertheless, participants living in the contaminated area had been informed about this contamination mainly by the media, especially by the local newspapers. Participants of the control group were living in cities with similar living conditions and size. After filling out the questionnaire, the participants received a small compensation ($ 12,--).

2.2.2. Sample

A sample of 80 participants participated in the study, 40 of which were living in the contaminated area and the other 40, the control group, were from areas in Switzerland, which were similar regarding the population structure, but which had not been exposed to any contamination.

2.2.3. Questionnaire

We developed a questionnaire consisting of three parts with questions to be answered on a seven point scale or with yes - no - choices. We chose these types of scales because many people have difficulties if they have to estimate the probabilities of risks[11]. The first part entailed questions about the risk perception of the soil contamination in the contaminated area and in general, including the path of pollution, groups being especially exposed to risk, and a description of the risk. In addition, the risk had to be evaluated by the characteristics shown in Table IV, which had to be answered on a seven-point scale. These items are similar to Slovic[12] and were adapted to the special situation of heavy metal environmental risk.

In the second part of the questionnaire the participants evaluated the risk of the contaminated soil and other types of risk regarding the criteria

- Voluntariness
- General knowledge about the risk
- Chronic or catastrophic potential
- Fear, and
- Health damage

We developed this part to analyze similarities between the risk caused by heavy metal contamination and risks caused by genetic technology, smoking, nuclear power, preservatives, oil contaminated soil, the ozone hole, and beef consumption. The comparison based on studies by Slovic or Schubert[12,13].

With this design we tried to analyze factors of risk perception and the similarities or differences to other studies, in which participants were not directly exposed to a specific risk. To do that we compared the factor structures of the risk perceptions of exposed and non-exposed participants.

In addition, we wanted to analyze similarities and differences in the risk perception between a low risk heavy metal contamination and other risks. Thus we did not compare the risk perception of laymen and experts[14,15], but between laymen living in contaminated and non-contaminated areas.

In the third part of the questionnaire the participants had to evaluate three variants of decontamination methods. There were two variants of sound decontamination methods using hyperaccumulating plants (willow and tobacco). The efficiency of these variants to reduce heavy metal contamination was already investigated for the area the exposed participants lived in[16]. The third variant was a traditional method excavating the soil and treating it chemically or storing it on a disposal site.

We described the variants to the participants in a standardized way, using text and pictures. The descriptions were created in collaboration with scientists investigating these decontamination methods. All three variants had to be valuated regarding their effectiveness, aesthetics, cost - benefit ratio and negative environmental impacts. In addition, the respondents had to valuate decontamination methods in general and especially regarding the degree of acceptance of the decontamination methods in their own area. Using these data we wanted to find out if affected people accept bioremediation methods. The results of this part of the study will be the basis of a transdisciplinary communication strategy between science and affected laymen to guarantee the use of the new decontamination methods in practice.

2.3. Results

2.3.1. Participants

The average age of the 80 participants was *M*=47.7 years (min=24, max=76). Half of the persons were male and half were female, and 66 (83%) had children. The average living time in the contaminated area was =19.7 years (min=1, max=76). 65 (81%) of the participants owned a garden and 47 (59%) consumed fruit or vegetables from their own garden. 57 (71%) persons owned their own land. 19 (24%) of the participants were smokers. There were no significant statistical differences in these data between the exposed and the non-exposed group.

2.3.2. Perception of local and general risk

At the beginning, we analyzed if exposed people perceive the risk of their contaminated place of residence as higher than non-exposed people.

This hypothesis was tested by a one-factorial ANOVA with repeated measurement for the four questions (dependent variables):

- Is soil contamination in general a problem in Switzerland?
- Is soil contamination at your place of residence a problem?
- Is soil contamination at your place of residence risky for you?
- Is soil contamination at your place of residence risky for other people?

All questions had to be answered on a seven point scale with 1=low and 7=high. We found interactions between the groups, significant differences between the groups, and significant differences within the measurement, all of which are shown in Table I.

Table I. ANOVA (repeated measurement) table for the perception of soil contamination at the place of residence and in general

Source	Df	F	Sig.
Exposure	1	6.6	<.01
Risk[1]	3	42.1	<.0001
Exposure* risk	3	14.7	<.0001

Note: $N_{exposed}$=34, $N_{non\text{-}exposed}$=36, $Mean_{exposed}$=3.87, $Mean_{non\text{-}exposed}$=3,10. Missing values occur because not all participants answered all questions. *Risk* refers to the four risk questions (dependent variables).
The factor risk consists of the three repeated measurements using the items:

- Is soil contamination in general a problem in Switzerland?
- Is soil contamination at your place of residence a problem?
- Is soil contamination at your place of residence risky for you?
- Is soil contamination at your place of residence risky for other people?

As expected, exposed people perceive the risk of soil contamination in general as higher than non-exposed people ($M_{exposed}$= 3.9, $M_{non\text{-}exposed}$= 3.1, $p < .01$). Exposed people also perceived the risk for themselves and for other people as higher than the control group (see Fig. 1). However, they distinguished in an appropriate way between the general risk of contaminated soil and the risk at their place of residence. In contrast to their personal risk at their place of residence, they perceived the general risk in Switzerland as lower than the non-exposed participants. Thus, exposed people perceived only their specific risk at the place of residence higher, while they perceived the general risk at other areas lower that non-exposed people (see also Fig. 1).

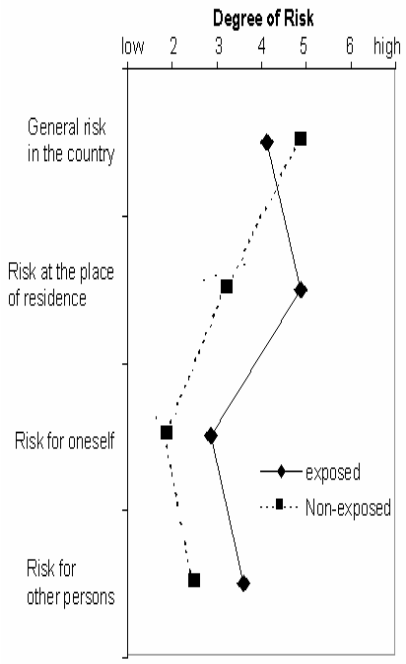

Fig. 1. Means of risk perception of exposed and non-exposed people. Exposed people perceive only their specific risk at the place of residence higher, while they perceive the general risk lower than non-exposed people.

2.3.3. Perception of different risk sources

To analyze similarities and difference in the perception of different risks, the participants rated the risk of the following sources[13,17]:

- Genetic technology
- Smoking
- Nuclear power
- Preservatives
- Oil contamination
- Ozone hole
- Consumption of beef
- Heavy metal contamination

The risks were evaluated by the following criteria:

- Voluntariness
- Knowledge about the risk
- Catastrophic potential
- Fear
- Health damage

To analyze the dimensions of risk perception, we calculated a factor analysis with the risk criteria using varimax rotation. This analysis resulted in three factors: *dread risk* (Eigenvalue = 1.59, percentage of variance = 31.9%), *control* (Eigenvalue=1.33, percentage of

variance = 26.7%) and *catastrophic risk* (Eigenvalue = 1.00, percentage of variance = 20.1%), which are similar to the factors of Slovic[12] or Schubert[13]. These factors explain 78.6% of the total variance. No difference in the structure of the factors could be found for gender or exposure of the participants. The factor analyses for exposed and non-exposed participants resulted in the same three factors. We did not find any significant differences in the *factor scores* between exposed and non-exposed participants (p=.79, F=.07, df=1). Factor 1 *dread risk* consists of the variables fear (r=.85) and health (r=.87). Factor 2 *control* is made up by voluntariness (r=.73) and knowledge (r=.84). The third factor is represented by the variable *catastrophic potential* (r=.97). We present the scores of all risks on these three dimensions in Table II.

Table II. Factor scores of the risks on the three factors dread, control and catastrophic

Risk	Dread risk	Control	Catastrophic risk
Beef	-0,74	-0,49	-0,06
Preservatives	-0,63	0,19	-0,19
Genetic technology	-0,17	0,81	-0,22
Nuclear power	0,15	-0,06	1,28
Heavy metal contamination	*0,08*	*0,43*	*-0,31*
Oil contamination	-0,005	0,23	0,29
Ozone layer depletion	0,79	0,31	-0,22
Smoking	0,47	-1,3	-0,55

Note: High scores implicate dread, uncontrollability and catastrophic risk. The factor loadings indicate a correlation between a risk and a factor.

In the following sectors we describe the attributes of the different risks, analyzing their loadings on the three dimensions. The risk of eating beef can be described as not dreadful and controllable. Both loadings are negative (dread: -.74, control: -.49) on these dimensions. The risk of preservatives is similar to beef regarding the dreadfulness (dread: -.63). However, it has loading near 0 regarding control and catastrophic risk. The risk of genetic technology loads differently on the dimensions than the two risk types above. It has a very high loading on the dimension *control* (.81). That means people rated it as very uncontrollable. In contrast to that, the risk of nuclear power was very dreadful to the participants of the study (catastrophic risk: 1.28).

In this study we stressed the perception of the risk of heavy metal contamination. It is highest on factor 2 *control* (r=.43). It is a risk, which is perceived as more or less uncontrollable. It loads slightly negatively on factor 1 *dread risk* (r=.01) and negatively on *catastrophic risk* (r=-.32). It may be compared to other environmental risks like pesticides, asbestos and cadmium in the model of Slovic[18].

It is interesting that the risk of an oil contamination shows different loadings than the heavy metal contamination. The respondents rated the oil contamination similar to the heavy metal contamination regarding controllability, but rated them differently regarding the catastrophic potential (catastrophic risk: .29). The perception of a higher catastrophic potential

could be influenced by the occurrence of accidents causing heavy contamination of soil or water.

Another group of more dreadful risks is the ozone layer depletion and smoking. Both were regarded as very dreadful (.79, .47) and less catastrophic (-.22, -.55). They differ regarding their controllability. While the ozone layer depletion was regarded as less controllable (.31), smoking was regarded as very controllable (-1.3).

In general the risks show different factor scores. To analyze these differences we calculated an ANOVA for repeated measurement with the risks as independent variable and the factors as dependent variables. This analysis showed that the risks were significantly different in their factor scores ($p<.0001$, $df=7$, $F=39.2$) and that there was an interaction between the risks and the factors ($p<.0001$, $df=14$, $F=27.3$).

The result of the factor analysis corresponds to other studies. The factor structure of the risks is similar to the well-known structure of Slovic[18], which also could be replicated by Schubert[13]. There are gender differences in the valuation of the specific risk criteria of different risks, like in many other studies[13,18,19], but there are no gender differences in the perception of the heavy metal contamination. There is, though, a tendency for non-exposed people to show gender differences ($M_{female}= 5.8$, $M_{male}= 5.1$) while exposed people show no gender differences ($M_{female}= 5.2$, $M_{male}= 5.2$). However, these differences are not significant.

Looking on the ratings of heavy metal contamination by exposed and non-exposed people regarding voluntariness, knowledge, catastrophic potential, fear, and health damage, we found significant differences in general (ANOVA for repeated measurement $p<.0001$, $df=4$, $F=68.8$) and in the ratings of catastrophic potential ($p<.02$) and fear ($p<.05$). Exposed people judged the heavy metal contamination as less catastrophic and less fearful, while the other ratings did not differ between exposed and non-exposed respondents.

Though we could not find gender differences in the *factor structure*, there are gender differences in the *perception* of the risks. An ANOVA for repeated measurements with "gender" as the independent variable and "perception of the risk criteria" (the criteria are presented in Table IV) as repeated measurements showed a significant gender difference ($p<.0001$, $df=1$), but no significant interaction. The male respondents rated the criteria significantly lower than the females ($M_{female}= 4.0$, $M_{male}= 3.6$), who seemed to be more risk averse.

To group the different kinds of risks, we did a cluster analysis (between group linkage, squared Euclidean distances). The dendogram of this analysis is presented in Fig.2.

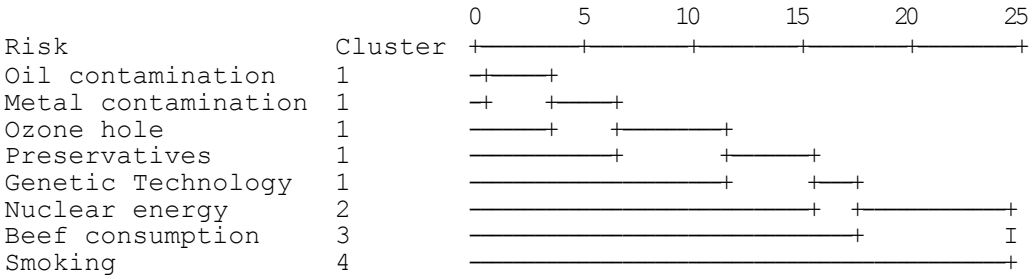

Fig. 2. Dendogram of the cluster analysis of the risks (four cluster solution, between groups linkage with squared Euclidean distances).

In a four-cluster solution, the risks *nuclear energy*, *beef consumption* and *smoking* differ from the other kinds of risks. *Oil* and *metal contamination* are most similar, followed by *ozone hole*, *preservatives*, and *genetic technology*. Nuclear energy as a risk with high catastrophic potential and also beef consumption, and smoking as voluntary risks distinguish from heavy metal contamination.

2.3.4. Preferred decontamination methods

With the third part of the questionnaire we checked if the participants preferred sound decontamination by hyperaccumulating plants to a classical decontamination by excavating the soil in their own gardens.

At first we want to mention that the participants living on the contaminated sites thought that a decontamination of their land was necessary. They were asked on a seven point scale with 1=not necessary in any way to 7 = absolutely necessary and rated this question with M=4.9, which was significant higher ($p<.0001$) than the rating of non-exposed participants (M=2.7).

In Fig. 3 one can see that the participants distinguished between the three variants regarding aesthetics, effectiveness, costs and environmental performance. However, there is no significant difference between exposed and non-exposed people in the valuation of the variants.

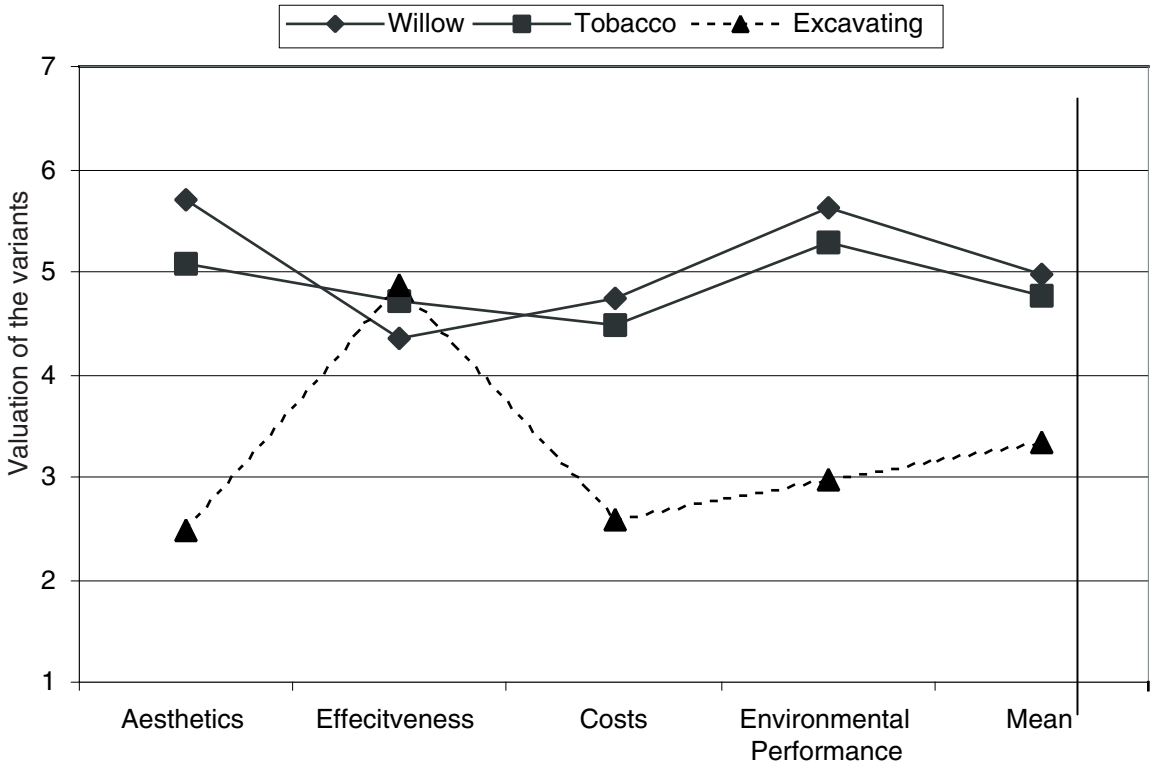

Fig. 3. Means of the valuation of the different decontamination variants (independent variable) regarding aesthetics, effectiveness, costs and environmental performance as dependent variables and the overall means. 1=not necessary in any way, 7=absolutely necessary. There is a significant difference in the valuation of excavating and the two bioremediation strategies using willow and tobacco (see also Table III).

There are significant differences between the variants (see Table III). In general the variant Bioremediation 1 (willow) (M=5.14) is rated best before Bioremediation 2 (tobacco) (M=4.86) and the Classical remediation (M=3.37).

The criteria aesthetics, effectiveness, costs and environmental performance distinguish significantly ($p_{\text{criteria}} < .0001$) as well. In addition there is an interaction between the criteria and the variants ($p_{\text{variants vs. criteria}} < .0001$). While the respondents rated the bioremediation variants positively regarding their ecology, their costs, and the aesthetics, they rated the classical remediation method positively regarding its effectiveness.

However, there is an interaction between exposure, the criteria and remediation variants, which bases mainly on the differences in the evaluation of the classical remediation. Exposed participants perceived the classical method as less aesthetic but as more effective than non-exposed participants.

Table III. ANOVA with repeated measurement with exposure and variant (bioremediation 1, bioremediation 2, and classical remediation) as independent variables and the criteria aesthetics, effectiveness, costs, and environmental performance as repeated measurement

Source	Df	F	Sig.	Mean
Exposure	1	.86	.355	Exposed = 4,54
				Non-exposed = 4.38
Variant	2	40.1	<.0001	Bioremediation 1 = 5.14
				Bioremediation 2 = 4.86
				Classical remediation =3.37
Criteria	3	13.0	<.0001	Ecology = 4.69
				Costs = 3.99
				Aesthetics = 4.46
				Effectiveness = 4.69
Exposure * criterion	3	1.3	.276	
Variant * criteria[1]	6	30.0	<.0001	
Exposure * variant	2	.3	.72	
Exposure * criterion * remediation	6	2.1	.05	

Note: We present the means of the valuation of the variants using the criteria aesthetics, effectiveness, costs, and environmental performance in Fig. 3.

The respondents judged the environmental performance of the decontamination (*M*= 6.2) as the most important criterion, before aesthetics (*M*= 5.8) and costs (*M*= 5.2). Less important was the duration of the decontamination (*M*= 4.3) , which is the main disadvantage of the bioremediation. In addition they rated the criteria significantly differently (N=76, df=3, F=26.6, sig.<.0001).

In general, the participants accepted a duration of the decontamination of *M*= 6.9 years. There is no significant difference between the affected and non-affected respondents.

As a next step we analyzed if sustainability as a precautionary issue is perceived as an important criterion to accept a bioremediation. We operationalized sustainability as "risk for future generations caused by soil contamination".

To analyze if the sustainability aspect has an impact on the acceptance of a decontamination we correlated the perceptions of the risk of heavy metal contaminated soil - measured on a seven-point scale -with the rating of the sense of a bioremediation.

We present the items describing the perceptions of the risk caused by heavy metal contaminated soils with their means and standard deviations in Table IV (N=80) In addition, the correlation to the question of whether a bioremediation makes sense is shown.

Table IV shows that the variable "risk to future generations" correlates highest with the rating of the sense of a bioremediation. The correlation is high for both the exposed and non-exposed participants. Non-exposed participants have even a higher correlation and rated this item higher than exposed participants. Another significant difference exists for the variable "decreasing/increasing of the contamination in the following years". Non-exposed participants

thought that it was more likely that the contamination will increase in the following years than exposed participants did.

Table IV. Means, standard deviation, and correlation coefficients of the items describing the perception of risks caused by heavy metal contaminated soil

I think that the risk caused by heavy metal	Group	Mean	SD	Correlation to
No risk – high risk	all	5,3	1.5	.32**
	exposed	5.2	1.5	.41**
	Non-exposed	5,4	1.5	.17
Controllable – uncontrollable	all	4,2	1.8	-.61
	exposed	4.2	1.9	-.11
	Non-exposed	4.2	1.6	.04
Not dreadful – dreadful	all	4.8	1.2	.36**
	exposed	4.8	1.2	.37*
	Non-exposed	4.9	1.2	.39*
Low risk to future generations –	all	*5.8***	*1.4*	.43**
high risk to future generations	exposed	*5.5*	*1.6*	.40*
	Non-exposed	*6.2*	*1.2*	,45**
Easy to reduce – hard to reduce	all	5.5	1.2	-.08
	exposed	5.7	1.1	-.26
	Non-exposed	5.4	1.4	.18
Decreasing during the following years –	all	4.4**	1.6	.09
increasing during the following years	exposed	3.9	1.6	.13
	Non-exposed	5.0	1.4	-.09
Known to experts – not known to experts.	all	4.3	1.7	.05
	exposed	4.1	1.6	.01
	Non-exposed	4.5	1.7	.08

Note: The italicized item describes the sustainability criterion. All ratings are done on a seven-point scale. ** indicates significance at the .01 level (2-tailed) and * indicates significance at the .05 level (2-tailed) both for correlation and ANOVA.

A multiple regression model, in which the variables were forced to enter the same equation, and a stepwise regression using the same items were significant for all participants and for the groups as well (p_{all}=.002, R_{all}=.51, $p_{exposed}$=.01, $R_{exposed}$=.65, $p_{non\text{-}exposed}$=.02, $R_{non\text{-}exposed}$=.62). The analyses showed that the sustainability item had the highest β-weight (β=.38, p=.02) and was the most significant variable to forecast the rating of the sense of the bioremediation method. The regression functions did not differ between the groups. Thus, a long-term risk affecting future generations seems to be the leading criterion to accept decontamination.

These results show that people prefer bioremediation methods especially if they stress sustainability issues. This may be underlined by the finding that 76 of 80 persons thought that a bioremediation makes sense because we have to *leave future generations clean soil*. This second "sustainability" question was asked in a yes/no mode at the end of the questionnaire. Because of the low negative environmental impact, these bioremediation methods are suited to decontaminate low contaminated sites over a long-term time period.

2.3.5. Perceived path of danger

The participants living on the contaminated sites were also asked what they think would be the main path, by which the soil contamination could become dangerous for them. Six paths were given and the participants of the exposed group could name more than one. The exposed group (N=40) rated eating of salads or vegetables from the contaminated soil as the most dangerous path for their own health (N=19). Ranking second was groundwater with N=15. The other four possibilities were seldomly named.

2.4. Discussion

We wanted to analyze the perception of the risk of contaminated soil by exposed and non-exposed people, attitudes towards sound decontamination methods using hyperaccumulating plants and the influence of long term aspects of sustainability on the acceptance of bioremediation methods. We could confirm our three hypotheses regarding four aspects. First, exposed people perceived the risk of the heavy metal contamination in their own area as higher as the general risk of contamination in Switzerland. Second, we could show by a factor analysis that the factors dread, control and catastrophic potential were relevant for the perception and valuation of risk, including the low dose heavy metal contamination risks. In addition, a cluster analysis showed that the respondents rated the risk of heavy metal soil contamination in a similar way like oil contamination, the ozone hole, preservatives and genetic technology. It was perceived as a risk that is indifferent with regard to dread with a medium range of uncontrollability and negative valuation with regard to catastrophic potential. Third, exposed and non-exposed participants preferred bioremediation methods to classical methods using excavation and chemical treatment of the soil, because they perceived the environmental and aesthetical performance of the bioremediation as important criteria. Last but not least, sustainability issues had a main impact on the acceptance of the use of bioremediation methods in the people's living area.

A comparison to other studies [13,18-20] shows that the participants in our study rated many different kinds of risk comparable to participants of other studies. They rated for example the risk of smoking with nearly the same value as the respondents of Schütz & Wiedemann[20]. In their study, the rating for the risk of smoking was *M*=6.29 (SD=1.33), in our study, the rating for personal health risk of smoking was *M*=6.27 (SD=1.17). A comparison to the study of Jungermann et al. [19] shows similar patterns in the perception of the risk of ozone layer depletion and genetic engineering as well. In both studies - ours and the one of Jungermann et al. - the average rating of ozone layer depletion is significantly higher than of genetic engineering. Thus, our sample seems to be comparable to other studies and not strongly influenced by the impact of the heavy metal contamination of their living area.

Comparing the factor scores of the risk of heavy metal contamination to the structure of Slovic[18] this risk can be compared with risks like cadmium usage, Trichlorethylene, pesticides, antibiotics, or asbestos insulation regarding the factors *unknown risk* and *dread risk*. The psychometric characteristics of these risks, including the risk of heavy metal contamination, seem to be similar. Thus the ratings of the participants seem to be reliable and correspond to other studies. That means that there are no significant structural differences in the perception of "low" environmental risk compared with other risks.

In addition, we found that exposed and non-exposed people did not differ in the factor structure of risk perception. For both groups we could extract the same factors. Thus, the risk of heavy metal exposure led to a more sensitive risk perception, but not to different patterns of perception. The quality of the risk and the exposure did not influence the risk perception in a way that changes the factors influencing risk perception. A transformation of the characteristics of the risk, which people are exposed to on other kinds of risk did not take place. Also, the influence of *fear* on the risk perception of exposed people did not have a major influence as it does in areas where the danger for human health resulting from the contamination is more dreadful[6,8]. In our "low dose" risk situation the respondents stressed long term effects like precautionary issues more than worry or anxiety. These factors play an important role in laymen's perception of nuclear risks[6]. In our study, the respondents stressed long-term effects of the risk. This is similar to the behavior of workers who are exposed to risk. Those seem to have a good knowledge and less fear about the risk. Very similar patterns could be found for power plant workers, knowing the risk they are exposed to, but not showing as much fear as non-exposed persons did[6].

The results showed that the participants were in favor of a sound decontamination by hyperaccumulating plants. The main impact on this result was the environmental performance of this variant of decontamination and the importance of sustainability or precautionary issues as criteria to decontaminate soil that is not heavily contaminated. By valuating the use of sound decontamination methods on the contaminated site positively, the respondents showed a kind of collective action and did not stigmatize the environmental problems. This is an important condition for a community to cope with its environmental problems [21].

But why were sustainability issues as an argument for bioremediation more important in the non-exposed group as in the exposed group? The answer could lie in the fact that one group really is exposed to the risk of the contamination. For them short-term improvements of the contamination plays a more important role as for non-exposed people. However, the exposed people thought that precautionary issues were the most important criteria to look upon while evaluating decontamination methods. Even if the present generation is affected by the environmental risk the needs of future generations played an important role.

In this study we analyzed the perception of measures of the public administration to handle environmental risk as well. This may be an important contribution toward fostering a dialogue between laymen exposed to environmental risks and scientists who want to develop new, sound decontamination methods that should be workable as well. We could show that the participants broadly accepted this new kind of environmental technology, because of its positive impact on sustainability. This result shows scientists who have been working on this new technology that the incorporation of sustainability issues in environmental risk management, environmental technologies, and communication will foster the acceptance of their technologies. Thus, the results of the study may help to understand and improve the communication between experts and the public regarding new decontamination methods.

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3. Emotional Concern in Environmental Risk Perception

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Abstract

Numerous studies, using the psychometric paradigm developed by Slovic, Fischhoff and Lichtenstein, show that risk perception of the public can be described on different risk dimensions, such as dread risk or unknown risk. The most part of these studies were analysing their data on an aggregate level, i.e. using mean scores for the participants. Thus, the results of these studies ignore individual differences. The main goal of this study is to get closer to the individual structure of risk perception. A questionnaire survey similar to those developed by Slovic et al. was conducted, but additional characteristics, such as emotional involvement, were integrated (N=112). In addition, questions and answer scales were formulated the way, participants had to judge the risk from a personal point of view. Beside classical risk sources as traffic or smoking we included ultra-low risks as cellular phone, heavy metal soil contamination, consumption of beef (BSE), and genetically modified food in our study. Factor analysis on the individual level shows that the factor dread, which we found on the aggregated level, was split in the two factors of emotional concern (Factor 1) and damage potential (Factor 2). The other factors are benefit, familiarity, and control. Regression analysis shows that the factor emotional involvement is an essential predictor for the perceived risk, the risk acceptance, and the desire for additional information. Whereas emotional concern and the potential damage are significant predictors of the perceived risk, emotional concern and benefit are the predictors for risk acceptance.

Key Words: Risk perception, risk acceptance, ultra-low risks, factor analysis, emotional concern

3.1. INTRODUCTION

3.1.1. The psychometric paradigm in risk research

Risk can basically be defined as a function of probability and harm. Thereby, it is not predetermined in what way the information of probability and harm are integrated. Risk could be defined, e.g., as the size of maximal possible loss, the product of probability and the size of loss, or the variance of the consequences (Scholz & Tietje, 2002). In general, laypersons and experts do differ in the way they judge a risk. Laypersons do underestimate the mortal rate for risk sources with statistical high mortal rates and overestimate the mortal rate for risk sources with statistical low mortal rates (Fischhoff et al., 1981). Moreover, laypersons do not only consider probability and harm in their risk perception.

Whereas Star (1969) proposed, that the risk acceptance is given, if the risk is approved by the behaviour of the society, in the sense of 'revealed preferences', Fischhoff et al. (1978) argued that persons have to be asked, if they accept a risk, in the sense of 'expressed preferences'. This was the starting point of a shift to a so-called psychometric paradigm in psychological risk research. A series of studies could show very well that people are taking beside the quantitative information of probability and harm also qualitative characteristics into their consideration, when they have to judge a risk (Slovic et al., 1980; Fischhoff et al., 1981, Slovic et al., 1985; Slovic, 1987; Slovic, 1992). The goal of these studies was to identify the cognitive and evaluative structure of the risk perception. Thereby, the use of factor analysis as method was very crucial.

Slovic, Fischhoff and Lichtenstein (1980) could identify some relevant characteristics, such as familiarity, involuntary, or catastrophic potential, and reduce them into the 3 factors dread risk, unknown risk, and exposure. The factor dread risk consisted of characteristics such as uncontrollable, global catastrophic, fatal consequence, high risk to future generation. Nuclear plants or nuclear weapons have high loadings on this factor. The factor unknown risk included characteristics such as risks unknown to science, unknown to those exposed, new risk or not observable. Here, genetic engineering yields high scores. The third factor was representing the number of people exposed to the hazard and the degree of one's personal exposure. The higher a risk source was rated on these three factors, especially on the factor dread, the higher was its perceived risk. Other studies found different but mostly similar factors (Slovic et al., 1985; Slovic, 1987; Slovic, 1992). Particularly, the third factor exposure could be not confirmed.

3.1.2. Shifting to an individual perspective

The psychometric paradigm can obviously be declared as a very dominant and successful approach in risk research. It allows, by using aggregated data over participants (for each risk source and characteristics the mean of the ratings of all participants), a comparison of the different risk sources and to represent them in a factor space, i.e. a cognitive risk map (Slovic, 1987, see Figure 1 & 2). Nevertheless, one problem of this method is, as it is used by most part of the authors, that it less describes the risk perception than the risk sources. As a result, individual differences, which could give a look on the individual processes involved in risk perception, are covered.

Some authors already compared the over participants aggregated factor analyses with a non-aggregated individual solution (Marris et al., 1997; Langford et al., 1999; Karger &

Wiedemann, 1998). Individual differences were found particularly in the characteristics describing the context rather than the risk source. They found individual differences in the characteristics knowledge (Marris et al., 1997), control and familiarity (Karger & Wiedemann, 1998), and the extent risk are perceived as horrifying (Langford et al., 1999; Marris et al., 1997). On the individual level, the factor solutions and the correlation were quite similar to the aggregated level (Marris et al., 1997). Only the correlation between knowledge and perceived risk magnitude could be not confirmed on the individual level.

The formulations of the items could also have an influence on the judgements. If the items are formulated in a general way, e.g. are people afraid of the risks instead of are you afraid of the risks, it reflects only a rather general attitude and does not tell very much about the individual risk perception. Thus, the change of the questionnaire items to a more personal formulation could be a good way to get closer to an individual perspective. A quite substantial difference could be found between the general risk ratings, as it is usually used in the psychometric risk research, and the personal risk ratings. There is a consistent optimistic bias concerning personal risks, called unrealistic optimism (Weinstein, 1984, 1989, Sjöberg, 1998, 2000).

Considering that the factor solution depends on the characteristics included in the analysis, the factor solution might change by adding additional characteristics. By analysing the trend in risk perception and decision making research, one finding is that to the role of emotions should be paid more attention (Schwarzer, 2000; Lerner & Keltner, 2000; Lopes, 1987; McDaniels et al., 1995; Karger & Wiedemann, 1998; Baron et al., 2000; Rundmo, 2002; Sjöberg, 1998; MacGregor, 1991). Worry seems to be a strong predictor for risk perception (MacGregor, 1991; Sjöberg, 1998a; Baron et al., 2000). In the psychometric paradigm one of the characteristics is fear (even not always included). But fear is not the only emotion which can influence the risk perception, also other emotions are affecting the risk judgements (Lerner & Keltner, 2000). Thus, in our own study, we included an additional characteristic, which should cover the emotional influence: emotional involvement. To assess the emotional involvement, we asked the people in how far they are emotionally involved and feel concerned about the risk source.

Furthermore, we included the perceived probability of harm for oneself and the perceived severity of harm for oneself. As the psychometric approach could stress very well the importance of qualitative characteristics, e.g., familiarity or control, the quantitative components of probability and harm were often neglected. However, several researchers have shown that this quantitative information plays also a crucial role in the risk perception of lay-people (Gardner & Gould, 1989; Sjöberg, 1993; Holtgrave & Weber, 1993, Borcherding, Rohrmann & Eppel, 1986; Karger & Wiedemann, 1998). It might be interesting to investigate the relative importance of these characteristics by including them in the same analysis. We also included the perceived benefit, which was not a characteristic in the original studies of Slovic et al. (1980, 1985). In general, a risk source also has its positive aspects. Thus, it can be distinguished between two risk concepts, the 'pure risk' and the speculative risk' (Fishburn, 1982). The latter is also considering the positive aspects of a risk.

In conclusion, one main goal of this study is to get a better understanding of the individual process in risk perception by changing to an individual level in the factor analysis, changing the formulations of the items into more personal ones, and adding additional characteristics such as emotional involvement. Taking the characteristics, i.e. the resulting factors as independent variables, we are interested in four dependent variables. Of course, the

perceived personal health risk and the risk acceptance are very central. Beside the risk acceptance the desire for additional information should play a key role in risk communication as well, and thus we included the desire for additional information as third dependent variable. We wanted also know, in how far people are focusing more on the probability or on the harm.

3.1.3. Ultra-low risks

Beside the choice and the formulation of the risk characteristics also the choice of the risk sources may affect the results. Almost in the last two decades environmental risks with very low probabilities and low or uncertain damage potential become more important, such cellular phone (the use of cellular phones or living near a transmitter) and the consumption of genetically modified food or beef. The latter means the risk of BSE. As lay-people do generally have problems to deal with probabilities (Hanson, 1989; Gigerenzer, 1997; Phillips, 1977, Scholz, 1987), it might be interesting to see how they judge such risk sources with very low probabilities. In addition, we included the popular high health risks of traffic and smoking, and also the risk of nuclear energy in our study. We wanted to compare these three classical risks with the ultra-low risks of cellular phone, heavy-metal soil contamination, the consumption of genetically modified food, and the consumption of beef (BSE).

3.1.4. Research questions

According to the above mentioned theoretical and methodological considerations the following research questions can be formulated: 1) Does the factor-solution change if data is aggregated over risks instead of an aggregation over individuals? Which factors can be found? 2) Does the factor-solution change if additional characteristics, e.g. emotional involvement, are added? What are the best predictors for 3) the personal risk perception, 4) the risk acceptance, and 5) the desire for additional information on the individual level? 5) Where are the risk sources arranged in the factor scenery?

3.2. METHOD

3.2.1. The questionnaire

We used a questionnaire similar to other questionnaires used in the area of the psychometric paradigm. The seven risk sources are described at the beginning of the questionnaire (see Table I). The questionnaire contains 21 items, i.e. 17 risk characteristics and 4 dependent variables, such as perceived risk, risk acceptance, weighting of harm versus probability, and desire for additional information (see Table II). 12 of the 17 characteristics were adapted from Slovic et al. (1985) and Slovic (1987). We formulated some of these items in a more personal way than the original formulation was, e.g. instead of a general fear we asked the personal fear. Five additional characteristics were added such as emotional involvement, the perceived probability of harm for oneself, and the expected severity of harm for oneself, and the societal and personal benefits. The items had to be answered on a bipolar five-point scale. Participants had to judge all the seven risk sources with the 21 items. Thus, they had to make 147 judgements.

Tab. I: Description of the risk sources at the beginning of the questionnaire.

Risk source	Description
Cellular phone	Electromagnetic fields (Electro smog) resulting from the use of cellular phones or from base stations.
Genetically modified food	Consumption of genetically modified food.
Consumption of beef	Consumption of beef, risk resulting from BSE.
Heavy-metal soil contamination	Soil is contaminated with heavy metals (e.g., cadmium, copper, and lead) at the residence.
Nuclear energy	Nuclear plant or transport of nuclear material. Risk of radiation.
Smoking	Smoking actively or passively.
Traffic	Joining the traffic actively or passively..

The following questions (control variables) had to be answered at the end of the questionnaire: 1) Do you own a cellular phone? 2) How important is the communication by cellular phone for you? 3) How many minutes you approximately use a cellular phone by week? 4) Are you vegetarian? 5) Did you stop to eat beef for the time being? Of course, age and gender were assessed, too.

3.2.2. Participants

112 Swiss high-schools students (29 male and 83 female) participated in this study. The average of the age of the participants was *M*=17.8 (*min*=16, *max*=21). 25 participants (22.3 %) were smoking and 15 (13.4 %) were a member of a 'green' organisation. Whereas 22 participants (19.6 %) answered being vegetarian, 40 participants (35.7 %) told that they do not eat beef for the time being.

Tab. II: Questionnaire items.

Item		Description	Poles of the scale	
			1	5
1	Familiarity	Is this source of risk new and unknown or familiar to you?	new/ unknown	very familiar
2	Level of knowledge	How do you estimate the extent of your knowledge about the risk/ risk source?	no knowledge	precise knowledge
3	Desire for additional information**	Do you wish you could have further information?	sufficient knowledge	pronounced need for additional information
4	Emotional involvement*	To what extent are you emotionally involved and feel concerned?	do not feel concerned	feel very much concerned
5	Personal exposure	To what extent are you personally exposed to the risk/ risk source?	not exposed	highly exposed
6	Involuntary	In how far you are taking this risk voluntarily?	voluntarily	involuntarily
7	Control/Uncontrollable	To what extent negative consequences can be prevented by personal skills or taking care?	uncontrollable	easy to control
8	Severity of consequences	If negative consequences appear, how severe they would be?	not fatal	very fatal
9	Possibility of death	May this risk source cause death?	impossible	definitely to expect
10	Catastrophic potential	Do negative consequences appear timely distributed (chronic risk) or do they affect many persons at once (catastrophic risk)?	chronic	catastrophic
11	Fear(*)	Do you personally feel afraid about the risk/ risk source?	not afraid	very much afraid
12	Personal probability*	How do you judge the probability that you are personally affected by negative consequences of this risk source?	very unlikely	very likely
13	Personal harm*	How do you judge thereby the possible negative consequences for you?	no negative consequences	very much negative consequences
14	High risk to future generations	To what extent negative consequences could occur to future generations?	no negative consequences	very much negative consequences
15	Dread/ Threat	To what extent the risk is a threat for you?	no threat	dominant threat
16	Weighting of probability and harm**	Would you judge the amount of risk rather by the probability or the (maximal) possible harm?	probability	harm
17	Personal benefit*	To what extent to you expect positive consequences for yourself?	no positive consequences	very much positive consequences
18	Societal benefit*	To what extent to you expect positive consequences for the society?	no positive consequences	very much positive consequences
19	Equitable distribution of benefit and risk	In how far risks and benefits are equitable distributed between different groups?	unfair distribution	equitable distribution
20	Personal risk**	To what extent, do you think, there is a health risk for yourself?	no risk	high risk
21	Acceptance**	In how far you can accept the risk resulting from the risk source?	I can not accept	I can accept very well

* These are additional characteristics, which were not used by Slovic et al. 1980 or Slovic, 1987 (*)

** These items were not included in the factor analysis. They were used as dependent variables in regression analysis.

3.3. RESULTS

3.3.1. Classical perspective: Aggregating over participants

Table III shows the means and the standard deviations of the perceived health risk and the risk acceptance for the risk sources. The perceived risk is higher for the "classical" risk such as traffic (*M*= 3.88), smoking (*M*= 3.50), and nuclear energy (*M*= 3.00) than for the ultra-risks. The consumption of genetically modified food is perceived the less risky (*M*= 2.46). Although traffic is perceived as the highest risk it is very well accepted (*M*= 3.38). Only cellular phone has higher values for the acceptance (3.74). Heavy-metal soil contamination (*M*= 2.31) and nuclear energy (*M*= 2.48) have the lowest acceptance. The relatively high standard deviations of perceived risk and risk acceptance for smoking ($SD_{\text{perceived risk}}$= 1.43, $SD_{\text{acceptance}}$= 1.40) and for consumption of beef ($SD_{\text{perceived risk}}$= 1.36, $SD_{\text{acceptance}}$= 1.38) can probably be explained by polarising the sample by smokers versus non-smokers and vegetarians versus non-vegetarians.

Tab. III: Means and standard deviations of Emotional involvement, Perceived risk, and Acceptance for different risk sources.

	Perceived risk		Acceptance	
Risk sources	M	SD	M	SD
Traffic	3.88	.92	3.38	1.15
Smoking	3.50	1.43	2.82	1.40
Nuclear plant	3.00	1.32	2.48	1.26
Genetically modified food	2.46	1.17	2.57	1.30
Cellular phone	2.96	1.18	3.74	1.21
Consumption of beef	2.54	1.36	2.68	1.38
Heavy metal contaminated soil	2.62	1.25	2.31	1.16

Concerning the weighting of harm versus probability (see Table IV), a mean above 3 indicates weighting in favour of harm, a mean below 3 indicates weighting in favour of probability. Whereas participants rated the component of harm as more important for the risk judgement of nuclear energy (*M*= 3.62) and smoking (*M*= 3.37), they rated the probability as more important for the risk judgement of cellular phone (*M*= 2.59) and consumption of beef (*M*= 2.61). Participants are not very much interested in having more information about smoking (*M*= 1.86) or traffic (*M*= 2.21), but they express a desire for additional information about genetically modified food (*M*= 3.54) and heavy-metal soil contamination (*M*= 3.28).

Tab. IV: Means and standard deviations of Weightings and desire for additional information for different risk sources.

	Weighting (harm versus probability)		Desire for additional information	
Risk Sources	M	SD	M	SD
Traffic	3.17	1.45	2.21	1.22
Smoking	3.37	1.45	1.86	1.21
Nuclear Plant	3.62	1.45	3.26	1.16
Cellular phone	2.59	1.36	2.91	1.46
Heavy metal soil contamination	3.05	1.37	3.28	1.19
Consumption of beef	2.61	1.35	2.52	1.24
Genetically modified food	3.06	1.40	3.54	1.25

Note: Weighting of 3 means that both components probability and harm should be taken in the same way into consideration. Weighting above 3 means that to the component of harm should be paid more attention than to the probability. Weighting below 3 means that to the component of probability should be paid more attention than to the harm.

In a first factor analysis we aggregated over participants by taking the mean values for each characteristic and risk source (see Table V). Three factors with an Eigenvalue above 1 could be found. The first factor had high factor loadings for personal harm, possibility of death, severity of harm, fear, emotional involvement, and threat. We called this first factor in analogy to Slovic et al. (1985) dread. The second factor loaded high in societal benefit, personal benefit, fairness, and personal exposure. The third factor control had high factor loadings for control, catastrophic potential (negatively), voluntary, and future generations (negatively). Thereby, the first factor explains 23%, the second 15%, and the third 14% of the variance.

Tab. V: Factor scores based on means for participants. Values below .40 are not indicated. Analysis was performed with the Varimax Rotation Method.

	Dread	Benefit	Control
Personal harm	.97		
Possibility of death	.95		
Severity of consequences	.93		
Fear	.92		
Emotional involvement	.74	.54	
Threat	.73	.55	
Personal probability	.64	.62	
Societal benefit		.97	.71
Personal benefit		.97	.69
Equitable distribution of benefit and risk		.95	.58
Personal exposure		81	.45
Control/Uncontrollable			.98
Catastrophic potential			-.86
Involuntary		.45	.82
High risk to future generations			-.77
Level of knowledge	.56		.73
Familiarity	.51		.69

Tab. VI: Factor weights of the risk sources for the three main factors.

	Dread	Benefit	Control
Cellular phone	-1.36	1.44	.43
Genetically modified food	-.73	-.14	-.26
Nuclear plant	.96	.124	-1.61
Consumption of beef (BSE)	-.10	-1.00	.93
Heavy metal contaminated soil	-.79	-1.05	-.89
Smoking	.92	-.57	1.21
Traffic	1.10	1.21	.19

Whereas traffic, smoking, and nuclear energy have high positive weights on the factor dread, cellular phone, heavy metal contaminated soil, and genetically modified have high negative weights (see Table VI). The factor benefit is spanned by cellular phone and traffic on the one hand, and of heavy metal contaminated soil and consumption of beef (BSE) on the other hand (see Figure 1). Smoking and the consumption of beef are perceived as easy to control. Nuclear energy and heavy metal contaminated soil are perceived as difficult to control (see Figure 2).

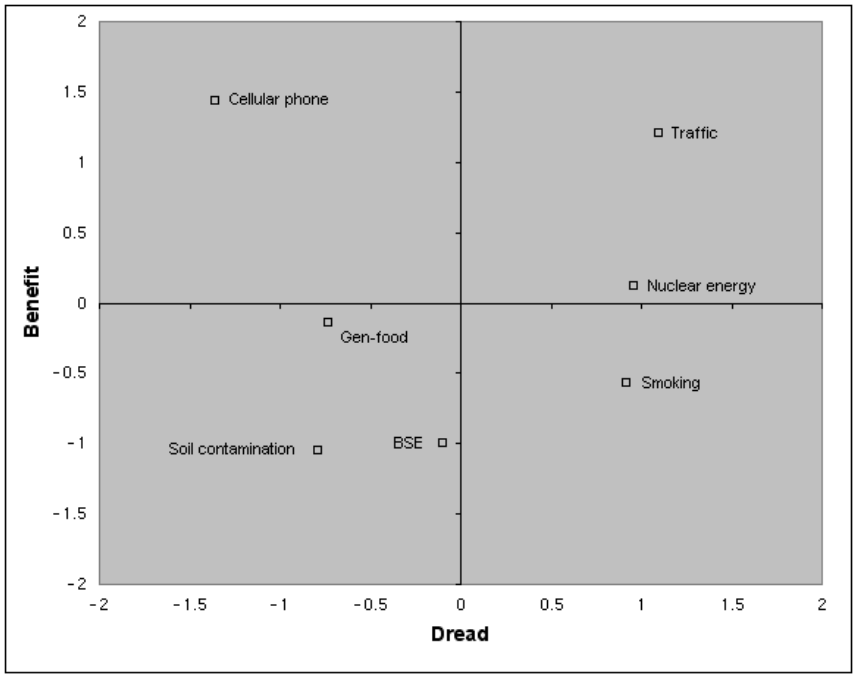

Figure 1: Factor space with the two factors dread and benefit

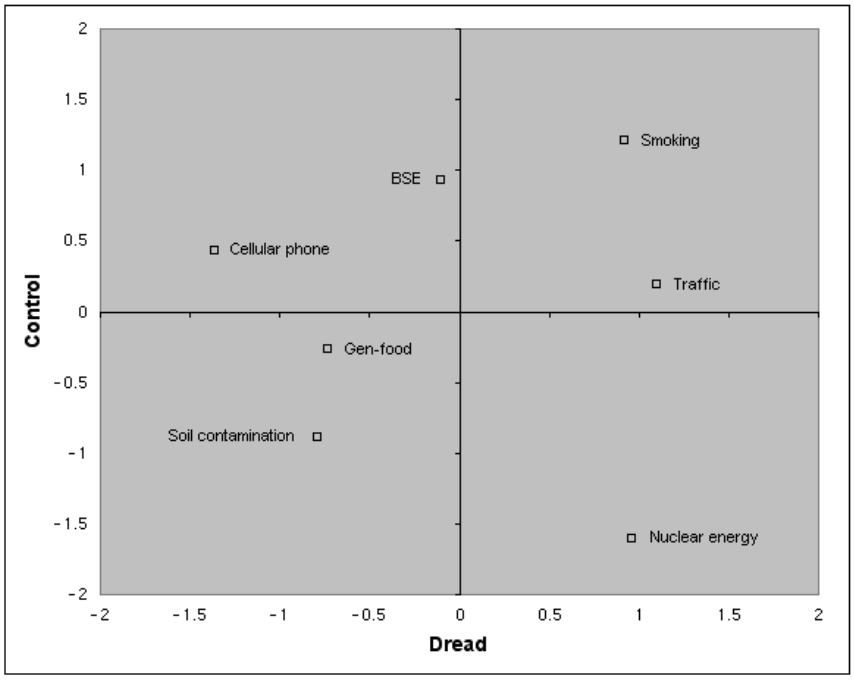

Figure 2: Factor space with the two factors dread and control

3.3.2. Individual perspective: Aggregating over risk sources

To investigate the influence of the factors on the perceived risk, the risk acceptance, the desire for additional information, and the weighting of harm versus dread, we performed a multiple regression analysis for each of these variables/factors. Whereas perceived risk (see Table VIII) seems to be determined by emotional concern (β= .573, p< .001) and damage potential (β= .217, p= .006), the significant predictors for risk acceptance (see Table IX) are emotional concern (β= -.260, p= .003) and benefit (β= .418, p< .001). The factors familiarity and control seem to have no significant influence. The five factors together explain 61.6% of the variance for the perceived risk and 49.9% of the variance for the risk acceptance.

Tab. VII: Factor scores based on means for the risk sources. Values below .40 are not indicated. Analysis was performed with the Varimax Rotation Method.

	Emotional concern	Damage potential	Benefit	Familiarity	Control
Threat	.80				
Emotional Involvement	.76				
Fear	.75				
Personal exposure	.73				
Personal probability	.66				
Personal harm	.43				
Possibility of death		.74			
Catastrophic potential		.65			
Severity of consequences		.64			
High risk to future generations	.44	.46			
Personal benefit			.83		
Societal benefit			.78		
Involuntary			.59		
Familiarity				.83	
Level of knowledge				.83	
Control/Uncontrollable					.69
Equitable distribution of benefit and risk					.69

Tab. VIII: Multiple linear regression model with the 5 factors resulting of the factor analysis as independent variables and perceived risk as the dependent variable; $R^2_{adjusted} = .616$.

	Perceived risk	
Predictors	β	p
Emotional concern	.573	<.001
Damage potential	.217	.006
Benefit	-.014	.862
Familiarity	.058	.460
Control	.057	.853

Tab. IX: Multiple linear regression model with the 5 factors resulting of the factor analysis as independent variables and risk acceptance as the dependent variable; $R^2_{adjusted} = .499$.

Predictors	Acceptance	
	β	p
Emotional concern	-.260	.003
Damage potential	-.057	.508
Benefit	.418	<.001
Familiarity	-.052	.541
Control	.033	.696

Emotional concern is the only significant predictor for the desire for additional information ($\beta = .389$, $p < .001$; see Table X). The weighting of harm versus probability is best predicted by emotional concern ($\beta = .372$, $p < .001$) and damage potential ($\beta = .236$, $p = .008$). This means, that the more people are emotionally concerned and the higher they perceive a damage potential, the more they weight in favour of the component of harm in their judgements. The five factors explain 42.6% of the variance for the desire of additional information and 47.6% of the variance for the weighting of harm versus probability.

Tab. X Multiple linear regression model with the 5 factors resulting of the factor analysis as independent variables and desire for additional information as the dependent variable; $R^2_{adjusted} = .426$.

Predictors	Desire for additional information	
	β	P
Emotional concern	.389	<.001
Damage potential	-.131	.145
Benefit	.050	.573
Familiarity	-.040	.656
Control	.094	.297

Looking at the control variables, participants who owned a cellular phone ($N = 88$) accepted more the risk of cellular phones ($M = 3.97$) than participants who did not own a cellular phone ($N = 24$, $M = 2.87$, $t = -4.138$, $p < .001$). There was also a positive correlation between the importance of cellular phone and its acceptance ($r = .50$, $p < .001$). Participants who were member of a 'green' organisation ($N = 15$) accepted less the risk of cellular phone ($t = 2.858$, $p = .005$). They were also more emotionally involved in this topic ($t = -2.476$, $p = .015$), and in the topic of genetically modified food ($t = -2.623$, $p = .010$). Whereas vegetarians ($N = 22$) did not differ in the risk acceptance of the consumption of beef, participants who told that they are not consume beef at the moment ($N = 40$) had lower values in the risk acceptance of consumption of beef ($t = 2.369$, $p = .015$m). Smokers ($N = 25$) perceived the risk of smoking higher ($M = 4.64$) than non-smokers did ($N = 87$, $M = 3.17$, $t = -5.022$, $p < .001$). On the other hand, smokers accepted the risk of smoking more ($M = 3.52$) than non-smokers ($M = 2.56$, $t = -4.641$, $p < .001$). No significant age or gender effects were found.

Tab. XI Multiple linear regression model with the 5 factors resulting of the factor analysis as independent variables and the weighting of harm versus probability as the dependent variable; $R^2_{adjusted}$ = .474.

Predictors	Weighting of harm versus probability	
	β	P
Emotional concern	.372	<.001
Damage potential	.236	.008
Benefit	-.04	.648
Familiarity	-.02	.800
Control	.146	.098

3.4. DISCUSSION

In the classical factor analysis we could identify the three factors dread, benefit, and control. Dread was rather identical with the dread risk factor of Slovic et al. (1985). The second and third factors were different. As expected the two different ways to aggregate the data produces different factor structures. On the individual level, we found 5 factors. Whereas on the classical over participants aggregated level dread is the first factor like in the original studies (e.g., Slovic et al., 1985; Slovic, 1987), on the individual level the factor dread was split into two components. We called the first factor emotional concern with high factor loadings of threat, emotional involvement, fear, and perceived exposure. The second factor was damage potential with high factor loadings of catastrophic potential or fatal consequences. Whereas the factor emotional concern reflects the personal and emotional side of the individual risk perception process, the factor damage potential considers the visible parts of dread. Thus, a distinction between the perceived potential damage (Factor 2) and the emotional involvement (Factor 1) must be made. The first factor reflects the importance of emotional characteristics/ processes in judging a risk and thus support the results of other researcher stressing emotional aspects (e.g., Finucane et al., 2000; Schwarzer, 2000; Lerner & Keltner, 2000; Lopes, 1987; McDaniels et al., 1995; Karger & Wiedemann, 1998; Baron et al., 2000; Rundmo, 2002; Sjöberg, 1998; MacGregor, 1991).

In our studies, in both of the analysis methods, benefit was an own strong factor, i.e. the second and the third factor. Our results are in contradiction to Slovic et al. (1980, 1985), who did not include benefit as a characteristic, but in line with Borcherding et al. (1986). Benefit and the perceived risk were equal predictors for risk acceptance in their study. Also other authors pointed the influence of the perceived benefit on risk perception and acceptance (Otway & von Winterfeldt, 1982; Alhakami & Slovic, 1994; McDaniels et al., 1995; Finucane et al., 2000).

Nevertheless, factor solutions were quite similar for the two analysis methods, with a first factor dread (split or not), following by benefit and control. This supports the thesis of Jungermann & Slovic (1993) that individual differences are a result of a different weighting of the factors, but the factor structure itself stays the same. Even the fact that the analysis produced different numbers of factors could be probably explained with the relative small number of risk sources, on the one hand, and the large number of participants, on the other hand, included in the analysis. However, the results of factor analysis are a function of the chosen characteristics, the chosen risks, the formulation of the items, the analysis method, and probably the sample as well.

Similar to the studies of Gardner & Gould (1989), Sjöberg (1993), Holtgrave & Weber (1993), Borcherding, Rohrmann & Eppel (1986), and Karger & Wiedemann (1998) lay people do also consider harm and probability in their risk judgements. Thereby, in our study the role of qualitative characteristics, particularly of emotional concern, was more important. But this could be the result of the risk sources we chose. Whereas participants weighted more the probability for the risk sources cellular phone and BSE, participants weighted more the harm for the risk sources nuclear energy and smoking.

The more a risk is high on the factor emotional concern and damage potential the more people focus on the component of harm and the less they consider the probability. This could be called the dread-effect. Gigerenzer (2004) gave a good but also sad example, how this dread-effect can even lead to higher risk behaviour. He could show that the numbers of victims died in car accidents because they stopped flying after the September 11 2003 were higher than the number of victims died on September 11. They avoid flying, because they had this horrible event in mind, but neglected the probability. Thus, this dread-effect has some important implications for risk communication. The fact that the desire for additional information is only determined by emotional concern is also noteworthy.

Concerning the risk sources, the ultra-low risks were contrasting the classical risks particularly in the factor of dread. Ultra-low risks had lower values in dread and they were - except cellular phone -lower or indifferent with respect to benefit. Cellular phone had the highest values for benefit and for the acceptance. Cellular phone seems to have a very high acceptance in the population of high-school students in Switzerland. Regarding the factor control, ultra-low risks and classical risks showed a broad variance. In conclusion, ultra-low risks are not perceived as high risks due to low values in the factor dread. The acceptance of these risks is dependent mainly of the perceived benefit.

The present study could give a brief insight into the psychometric paradigm and how qualitative characteristics can influence risk judgements. In our view, individual processes in risk judgements, particularly the role of emotions, should be further stressed in future research. Also there should be made further progresses to draw conclusions from the risk perception research and implement them in the risk communication context.

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4. Risk Perception of Heavy Metal Soil Contamination by High-Exposed and Low-Exposed Inhabitants: The Role of Knowledge and Emotional Concerns

Dirk Grasmück and Roland W. Scholz (2005)

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Abstract

Soil contaminated with heavy metals is a salient example of environmental risk. Consumption of vegetables cultivated on contaminated soil or direct ingestion of soil by small children can damage health. In contrast to other kinds of pollution or risks such as air pollution or exposure to ozone, the individual risk concerning soil contamination is highly dependent on the way one is exposed to the local source of risk. Thus, we wanted to know if risk perception varies according to the level of exposure. A quasi-experimental, questionnaire-based study was conducted in a community of the North West of Switzerland, where the soil is widely contaminated. The level of contamination varies with the distance from the source of the contamination, a metal processing plant. We investigated the perception of risk of heavy metal contaminated soil by inhabitants with high-exposure levels ($N = 27$) and those with low-exposure levels ($N = 30$). Both groups judged the risk for oneself similarly whereas the low-exposure group, when compared to the high-exposure group, judged perceived the risk for other affected people living in their community to be higher. Besides this exposure effect, risk perception is mainly determined by emotional concerns. Participants with higher scores in self-estimated knowledge tend to provide low risk judgments, were less interested in further information, showed low emotional concern and thus high risk acceptance. Contrarily, actual knowledge showed no correlation with one of theses variables. Judgments on the need for decontamination are determined by risk perception, less application of dissonance-reducing heuristics, and commitment to sustainability. The desire for additional information is not affected by missing knowledge but is affected by emotional concerns.

Key Words: Risk perception, environmental risk, heavy metal contamination, emotional concerns

4.1. Introduction

The risk assessment of experts is only part of the truth in a risk dialog. The risk perception of concerned people is the other. This distinction can be traced to the discourse on risk communication [1-3]. However, in contrast to other kinds of environmental risks such as air pollution or exposure to the ozone hole, the individual risk perception and risk acceptance of soil contamination is highly dependent on a person's exposure (or not) to the local risk source. Slovic et al. [4] already included personal exposure as a determinant of risk perception. Exposure had a positive impact on perceived risk and was part of the first factor, dread, in the early studies of Slovic et al. The second factor was unknown risk. In another study by Slovic, Fischhoff, and Lichtenstein [5], personal exposure and the number of exposed people constituted an own third factor. Marks and Winterfeldt [6] named the positive correlation of personal exposure and perceived risk as the not-in-my-backyard phenomena. But is the effect of exposure really so clear? How do exposed people perceive the risk? We conducted our study using a real life situation. Without doubt, a critical issue is how long people are exposed and how they react when they become aware of the exposure. If, for instance, people have lived on contaminated soil for years and do not (want to) change their residence, then we assume that dissonance-reduction [7-9] is at work and leads to an increase in the acceptance of the risk.

Whether a given risk seems acceptable is negatively correlated with the perceived risk and positively correlated with the perceived benefits. The risk acceptance becomes positive if the perceived benefits are outbalancing the perceived negative and harmful outcomes. According to Slovic risk perception is a rather general concept and "refers to various kinds of attitudes and judgments"[10]. The study of risk perception includes the investigation of the cognitive and affective processes involved and relies on risk judgments that are given by different populations of students and citizen groups.

In a previous questionnaire-based study, Weber et al. [11] compared the risk judgments of 40 inhabitants of Dornach with 40 people living in comparable, but not contaminated, communities. The people exposed to contamination knew and accepted that there was a problem in the area, but the risk itself, or the risk in general, was perceived to be lower by those exposed to contamination than by those not exposed.

In the study by Weber et al. [11], a member of the project staff was present when people filled out the questionnaire. During these rather interview-like meetings they collected some additional qualitative information. Participants were more than happy to speak about their local contamination problem and they were quite open in expressing their opinions. Based on this additional qualitative information certain variables could be identified, which seemed to be relevant for a better understanding of people's risk perception [12], such as 1) exposure differences in the village of Dornach itself, and individual differences in 2) knowledge, 3) emotional concern, and 4) the use of heuristics. However, these qualitative impressions did not allow one to draw any conclusions concerning how far these variables are related to each other or the influence they have on risk perception. Thus, the main goal of our study is to investigate the influence of these proposed variables on risk perception in an exploratory and quantitative way.

The relationship between exposure and risk perception respectively risk acceptance in Dornach itself was not clear in the study of Weber et al. [11]. They suspected that people who were living in close proximity to the metal factory, and were thus exposed most, rated the risk similarly or even lower than people living at some distance from the plant in an only marginally contaminated area. Contrary to the study of Weber et al. [11], which investigated exposed versus

non-exposed people from different communities, this study compares minimally exposed and highly exposed people within the same community. Because the level of contamination varies substantially in Dornach, the effective exposure and, thus the potential risk, varies for different inhabitants. This may, therefore, have an influence on the risk perception.

In a series of studies [11, 13] a great deal of variation the knowledge people had of the contamination problem was observed. In the case of Dornach information was provided by newspaper articles, through a newsletter, and in an informational meeting organized by the community council of Dornach. Although information was easily available for everyone in the same way, people differed considerably in their knowledge of the soil contamination problem. Some people were very well informed; they knew, for example, which heavy metals were included, the paths through which health damage could be caused, or which vegetables they should avoid growing, and subsequently eating, in contaminated gardens. Other people were missing some information or even had wrong ideas about the risk. They believed, for example, that the main problem resulting from soil contamination is the bad quality of ground water. Nevertheless, self-estimated knowledge and the desire for further information seemed to vary independently of the actual knowledge people had. In addition, they were unaware of the influence of knowledge on risk perception. This is consistent with other studies [14] showing that it is not actual knowledge, but rather self-estimated knowledge, that has an important influence on risk perception.

The extent to which people were emotionally involved in the problem of the local soil contamination also seemed to play an important role in the way they perceived the risk and made their judgments. Whereas some people were heavily emotionally involved and concerned about the situation, others did not show any concern and paid little attention to the situation. Emotionally involved people rated the risk more highly than less emotionally involved people. Other authors [15-23] have already pointed out the importance of considering an emotional component in risk perception. In brief, the main results of these studies were that worry increases the perceived risk. Schwarz [16] categorized the emotional impact on decision making according to the different steps in the decision process. Lerner and Keltner [17] noted that the influence of emotions on judgments is rather emotion specific.

During the five-year project on soil risk in Dornach in which the authors were involved [24, 25], we met a lot of people whose arguments were based on simple heuristics, which – from an environmental science perspective – seemed to be rather weak. These arguments, while sounding in some way logical, usually did not contain any scientific reasoning. Some people mentioned that there was an inhabitant in Dornach, who lived close to the plant, ate vegetables from his own garden, was always very healthy, and died very old. The more frequent appearance of snails on the site was another argument people used to argue that the risk of soil contaminated with heavy metals in Dornach could not be so bad. These are only two examples of heuristics, with which we were confronted. The function or the goal of these heuristics could be a reduction of cognitive dissonance [7]. The thoughts that people have in mind are probably of the nature: A risk exists at the place where I live – either I change my place of residence or the risk is not that bad. As far as we know, no people moved away due to soil contamination. Thus, we called these arguments dissonance-reducing heuristics. One mode of dissonance reduction is trivialization [9]. The arguments used by the residents of Dornach can be interpreted as a type of trivialization.

To obtain a better understanding of the aforementioned processes we constructed a questionnaire to record risk judgments and foundations of risk perception. In addition to the

already mentioned variables of knowledge, emotional concern, and dissonance-reducing heuristics, the questionnaire included questions on sustainability. The reason for this is that a commitment towards sustainability seems to be essential with respect to gaining votes for soil cleanup measures as found by Weber et al. [11]. Whereas Weber et al. [11] described the risk of soil contamination with certain characteristics taken from factor analysis [26] and compared it to other risk sources, the main focus of this study was to gain a better understanding of the individual processes underlying risk perception and risk acceptance. Furthermore, differences in coping with risk between people with high-exposure levels and those with low-exposure levels were explored.

According to the argumentation and theoretical considerations outlined above, the following research questions can be formulated. 1) What influence does exposure have on the risk perception of heavy metal contaminated soil and on the need for decontamination? 2) What influence do emotional concerns have on the risk perception of heavy metal contaminated soil and on the need for decontamination? 3) To what extent are exposure and emotional concern related to each other? What role is played by the knowledge components of 4) actual knowledge, 5) self-estimated knowledge, and 6) the desire for additional information? In which way do 7) dissonance-reducing heuristics and 8) thoughts about sustainability affect risk judgments?

4.2. Method

4.2.1. The case

The problem of heavy metal contaminated soil exists at many industrial sites all over the world [27]. One example of such a contaminated site in Switzerland is the community of Dornach, which is situated near Basel in northeast Switzerland and has approximately 6,000 inhabitants. In Dornach, the soil is heavily contaminated with heavy metals [28]. The primary cause for the contamination is a metal processing plant, which has been in operation since 1895. The installation of modern filtering systems in the early 1990s inhibits a further increase of contamination. Therefore, the soil contamination in Dornach is representative of refuse dumps [24, 29].

The soil is particularly contaminated with cadmium, zinc and copper, with cadmium having some risk potential [30, 31]. In Dornach, the health risk is not very high because of the medium to moderate concentrations and because of the small soluble fraction of cadmium in the soil. Thus, acute intoxication can be excluded. However, since the total content of cadmium is relatively high, a health risk cannot be excluded given any long-term exposure [32]. Chronic cadmium poisoning can result in kidney malfunctions and cancer.

There are different paths with respect to how the pollutants can arrive within the human organism [33]. The main pathways are 1) soil ingestion by infants, as they sometimes swallow larger amounts of soil material while playing outdoors, 2) consumption of the meat of animals, which grazed in the contaminated area, and 3) consumption of vegetables cultivated on local contaminated soil. The consumption of tuber plants like celeriac should be particularly avoided, since these types of plants accumulate a notable amount of heavy metals from the soil. In the case of Dornach only the first and third possible pathways are relevant. This is because the consumption of locally grown vegetables and the presence of children in the family can be seen

as indicators for personal exposure. Therefore, we assessed these variables and controlled their influence on other variables.
However, consequences are uncertain and, if they arise, do so with a large temporal delay. Experts are uncertain of whether, and if so the extent to which, a health risk needs to be considered in the real-world case of Dornach though the risk is relative, e.g., due to high pH values which lowers the bioavailability of heavy metals to plants [34]. Even if the risk of contaminated soil in Dornach is unclear, it is certainly not zero, at least in the areas with the highest concentrations. Moreover, the heavy metals will not disappear from the soil in the near future. Without decontamination, the problem of contaminated soil (and restricted soil use) will be bequeathed to forthcoming generations.

4.2.2. The design of the study

A quasi-experimental study investigated the perception of risk of heavy metal contaminated soil by people living in Dornach with either high or low exposure levels. These two groups were specified on the basis of a contamination map of cadmium [35]. The map of contaminated land in Dornach (see Figure 1) clearly shows that the level of contamination is correlated with the distance to the metal processing plant. The people in the high-exposure group lived in close proximity to the plant (up to a distance of approximately 350 m) where the estimated concentration of cadmium is 2 mg/kg soil or more and the probability of exceeding a threshold value of 2 mg/kg soil is at least .80. The people in the low-exposure group lived at a distance of approximately 400 m to 1.4 km from the plant, where the estimated concentration of cadmium is less than 2 mg/kg soil. We excluded people living far away from the metal processing plant and/or not on a contaminated area (where the estimated concentration of cadmium is between 0 – 0.5 mg/kg soil). People were unaware of their group membership, but it is commonly known in Dornach that the distance between one's residence and the metal processing plant, which is the source of the contamination, gives an approximate idea of the relative level of contamination.

While the local level of contamination and the distance between one's home and the metal plant are good indicators of personal exposure, other factors need to also be considered. People who eat vegetables or fruits grown in their own garden or by local producers are more exposed than those who do not. People with small children might have a special risk to their family, if the uncertainties in the soil measurement are taken into account and concentrations of far above 10 mg Cd/kg soil are considered likely. In addition, the duration of the exposure is also a key factor determining the level of the risk. Therefore, questions concerning the consumption of locally grown vegetables, the presence of children, and how long one has lived in the exposed area were included in our questionnaire.

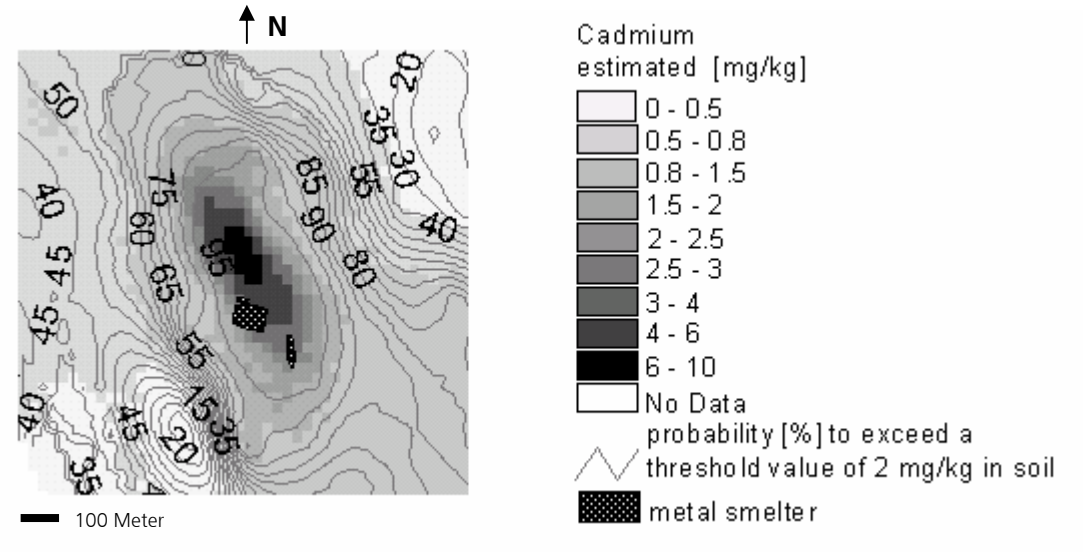

Figure 1. Map of cadmium contaminated land and the probability that a threshold value of 2 mg/kg soil is exceeded. Source: U. Schnabel, *Spatial Data Management and Decision Making for Soil Improvement Measures* (Dissertation No 15125, Swiss Federal Institute of Technology, Zurich, 2003).

4.2.3. The instrument

We constructed a standardized questionnaire, whose questions had to be answered on an 8-point scale. We also included some multiple-choice questions (see Table I). Partly because we conducted our study door-to-door and partly because we wanted to motivate as many inhabitants to participate as possible, we wanted to construct a rather short instrument with only a few meaningful items. In particular, there are very few households in the high-exposure area. Thus, we included rather holistic overall judgments instead of multifaceted questions examining various attributes. Such overall judgments should be a good way in which to encourage emotional involvement because of the holistic nature of emotions. We also included only overall judgments for the dependent variables, such as risk perception and need for decontamination. In fact, as far as we know from our own experience of interviews or contacts with the town council and other actors, these general and holistic judgments are predominant in Dornach. Thus, our items seem to be a good indicator for individual processes in this case.

From a psychometric point of view, the disadvantage of single item variables or short scales is one of limited information on reliability. Therefore, the interpretation of the results concerning the strength of an effect has to be made very carefully. Nevertheless, our work can be seen as a pilot study in which to obtain a better understanding of the Dornach case and of residents' risk perception on soil contamination. For a real robust, generalized interpretation, the results should probably be replicated.

Table I. Questionnaire items.

Variable/Question	Type
Emotional concern	
• To what extent do you feel concerned about the contamination problem?	8-point scale
• To what extent are you emotionally involved?	8-point scale
Actual knowledge	
• Which substances cause the health risk?	Multiple choice
• Which paths for human absorption are the most relevant ones?	Multiple choice
• Which vegetables or fruits should you avoid eating regularly?	Multiple choice
Self-estimated knowledge	
• Do you feel well informed about the problem?	8-point scale
• How do you estimate the extent of your knowledge in comparison to other inhabitants of your community?	8-point scale
Desire for further information	
• 1. Do you wish you could have further information?	8-point scale
Dissonance reducing heuristics	
... To what extent do you agree with the following statements?	
• There are examples of people, who lived close to the plant, ate vegetables from their own garden, were always very healthy, and died very old. This proves that the problem is not that bad.	8-point scale
• The more frequent appearance of snails shows that the situation is improving.	8-point scale
• Modern filter systems inhibit further contamination, thereby, solving the problem on a long-term basis.	8-point scale
• In Eastern Europe the situation is much worse.	8-point scale
• Other environmental problems are more important.	8-point scale
• Mobile communication (GSM-Transmitter) is an even greater health risk.	8-point scale
Thoughts about sustainability	
• Do you think about future generations with respect to soil contamination in Dornach?	8-point scale
• Should the soil, as a living part of our environment, be protected?	8-point scale
• Should the soil be cleaned even if there are no acute human health risks?	8-point scale
Risk measures	
• To what extent, do you think, there is a risk for yourself?	8-point scale
• To what extent, do you think, there is a risk for other inhabitants in Dornach?	8-point scale
Need for decontamination	
• To what extent do you favor the decontamination of the soil?	8-point scale
Control variables	
• Do you eat vegetables or fruits grown in your own garden or produced locally?	Yes/No
• If you have children, what is the age of your youngest child?	Open response
• How long have you lived in Dornach?	Open response
• Do you live in close proximity to the metal processing plant?	Yes/No
• What is your gender?	Multiple choice
• What is your year of birth?	Open response

As can be seen in Table I, emotional concern, related to the extent to which a person is concerned with the situation and feels emotionally involved, was assessed with two questions. These two items were highly correlated, with $r = .76$. Knowledge with respect to soil contamination was divided into three facets: actual knowledge, self-estimated knowledge, and the desire for further information. Actual knowledge was measured with three multiple-choice

questions. Participants could achieve a minimum score of 0 and a maximum score of 14. For example, we asked what the most relevant paths for human intake of the heavy metals prevalent in Dornach were. Self-estimated knowledge was assessed with two items, which correlated with $r = .68$. The desire for additional information was assessed with a single question. The construct of dissonance-reducing heuristics consisted of 6 items (*Cronbach Alpha* = .78), which were collected in a previous interview-based study [19] (see Table I). Three items examined thoughts concerning sustainability and the precautionary principle (e.g., "Do you think about future generations with respect to soil contamination in Dornach?"; *Cronbach Alpha* = .75). Regarding the dependent variable perceived risk magnitude, we focused on health risk and we distinguished between health risk for oneself and health risk for other inhabitants in Dornach, each measured with one item. A third dependent variable was the need for decontamination, again measured with one item. The control variables are also listed in Table I.

4.2.4 Participants

The investigation included 57 residents (33 male and 24 female) of Dornach. The low-exposure group consisted of 30 participants and the high-exposure group consisted of 27 participants. Unfortunately, due to the area's small size, we were unable to obtain more households in the high-exposure condition. While 26 participants (96.3%) in the high-exposure group answered affirmatively to the question of whether or not they lived in close proximity to the metal processing plant, only 13 participants (43.3%) in the low-exposure group did so.

The average age of the participants was $M = 50.5$ (*min* =18, *max* = 80). The majority of participants (45 or 78.9%) had children. The average length of time participants had been residents of Dornach was $M = 26.8$ years ($SD = 20.9$ years). Only people living in houses with gardens were included in the study and 40 of them (70.2%) consumed fruit or vegetables from their own garden or from local producers. There were no significant statistical differences in these data between the high-exposure and the low-exposure groups.

4.2.5. Procedure

The investigation took place in Dornach. The participants filled out a questionnaire, with one person on the project staff present to help in case participants had any questions. After filling out the questionnaire, the participants received a small box of chocolates for their efforts.

4.3. Results

The dependent variable risk perceptions/judgments was analyzed using a 2 (exposure: high vs. low) by 3 (emotional concern: high vs. medium vs. low) by 2 (risk object: oneself vs. other) ANOVA, with repeated measures on the last factor (see Table II). Exposure did not have a direct influence on the risk judgments, as indicated by the failure to obtain a significant main effect ($F = .01$, $df = 1$, $p = .92$). In contrast, the main effect of emotional concern on risk judgments was significant ($F = 15.9$, $df = 2$, $p < .001$). The object of risk (oneself or others) was also significantly related to overall risk judgments ($F = 30.8$, $df = 1$, $p < .001$), with the risk for others being generally rated higher than the risk for oneself ($M_{\textbf{risk}\text{ for oneself}} = 3.8$, $M_{\textbf{risk}\text{ for others}} = 5.1$). Emotional concern did not interact significantly with either exposure ($F = .72$, $df = 2$, $p = .49$) or with risk object ($F = 1.3$, $df = 2$, $p = .27$). There was, however, a significant interaction between exposure and the object of risk ($F = 7.3$, $df = 1$, $p < 0.01$). More specifically, whereas the low-exposure group perceived and judged the risk for other people to be higher than did the high-exposure group as expected, ratings of the risk for oneself were not higher for the high-exposure group than the low-exposure group (see Figure 2). Both groups perceived the risk for oneself similarly. No gender effects were found.

Table II. ANOVA summary table for risk perception judgments with exposure, emotional concern and risk object (repeated measurement) as independent variables ($N_{\text{high-exposure}} = 27$, $N_{\text{low-exposure}} = 30$).

Source	df	F	p
Exposure	1	.01	.921
Emotional Concern	2	15.9	<.001
Risk Object (risk for oneself vs. risk for others)	1	30.8	<.001
Exposure* Emotional Concern	2	.72	.491
Exposure* Risk Object	1	7.3	.009
Emotional Concern* Risk Object	2	1.3	.273
Exposure* Emotional Concern* Risk Object	2	.44	.648

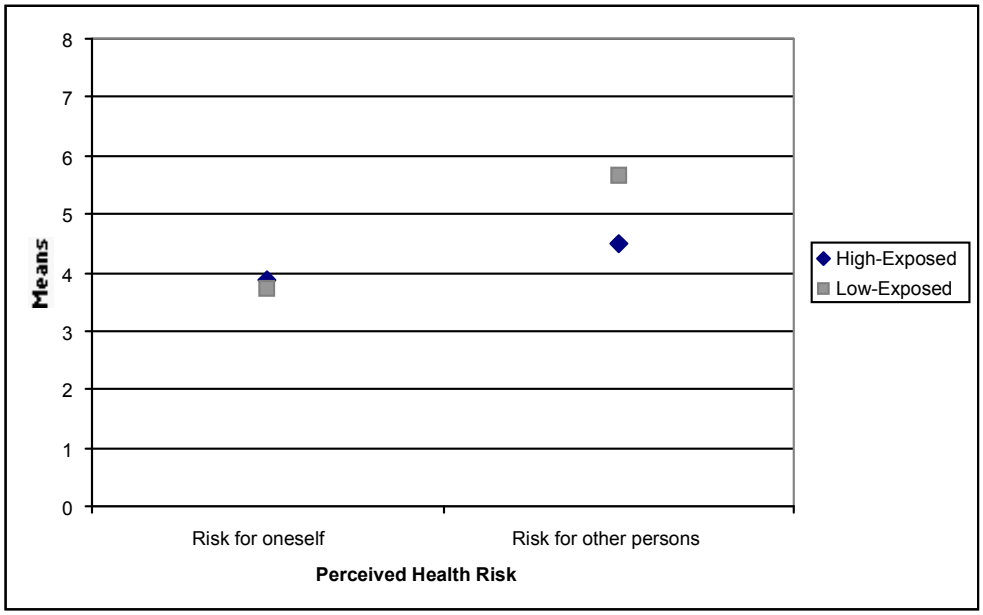

Figure 2. Mean risk judgments for oneself and for other persons as a function of exposure.

While the ANOVA revealed that emotional concern had a main effect on risk perception (see Table II), emotional concerndid not depend significantly on the exposure group ($M_{\text{high-exposed}} = 3.7$, $M_{\text{low-exposed}} = 4.6$). However, a point-biserial correlation analysis revealed that exposure correlates significantly with emotional concern ($r = .27$, $p < .05$). While the ANOVA examines the interaction between exposure and emotional concern factors in influencing risk judgments/perceptions, the correlation analysis examines in how far these two factors are related to each other. Thus, there seems to be a slight tendency that residents in the high-exposure group are less emotionally involved than those in the low-exposure group, but this covariance of exposure and emotional concern does not have an effect on the risk perception. Tests for exposure and other variables were not significant.

Table III presents the correlations between the different variables. Emotional concern correlated positively with the desire for additional information ($r = .34$, $p < .05$), with thoughts about sustainability ($r = .38$, $p < .01$), with risk for oneself ($r = .63$, $p < .01$) as well as risk for others ($r = .56$, $p < .01$), and with need for decontamination ($r = .51$, $p < .01$). It correlated negatively with dissonance-reducing heuristics ($r = -.37$, $p < .01$) and with self-estimated knowledge ($r = -.31$, $p < .05$). The implications are that people with high emotional concern are more likely to rate the risk as being higher, have a more pronounced need for decontamination, wish for more information about the problem, think more about sustainability and precaution issues, use less dissonance-reducing heuristics, and estimate that they know less about the problem. In other words, emotional concern seems to be very central to the process of risk perception.

Table III. Intercorrelations ($N = 57$) between variables.

	Emotional concern	Heuristics	Precaution	Actual knowledge	Self-estimated knowledge	Desire for information	Risk for oneself	Risk for others
Heuristics	-.37**							
Precaution	.38**	-.05						
Actual knowledge	-.16	.11	-.02					
Self-estimated Knowledge	-.31*	.43**	-.20	.36**				
Desire for Information	.34*	-.28*	.34**	-.11	-.35**			
Risk for oneself	.63**	-.21	.22	-.14	-.33*	.45**		
Risk for others	.56 **	-.34**	.33*	-.03	-.36**	.37**	.68**	
Need for decontamination	.51**	-.57**	.52**	-.09	-.42**	.51**	.38**	.51**

Note: Correlations with ** are significant at the 0.01 level (2-tailed). Correlations with * are significant at the 0.05 level (2-tailed).

The scores for actual knowledge covered the entire range between 0 and 14 (see Figure 3) and are bimodally distributed. There were two notable peaks, with people being either well informed or poorly informed. Actual knowledge correlated with self-estimated knowledge ($r = .36$, $p < .01$), but had no other significant relations to other variables (see Table III). On the other hand, self-estimated knowledge correlated negatively and significantly with perceived risk to oneself ($r = -.33$, $p < .01$) and to others ($r = -.36$, $p < .01$), with need of decontamination ($r = -42$, $p < .01$), and emotional concern, as already outlined above. It correlated positively with actual knowledge ($r = .36$, $p < .01$) and with the use of dissonance-reducing heuristics ($r = 43$, $p < .01$). The desire for additional information correlated most with need for decontamination ($r = 51$, $p < .01$) but also correlated significantly with all other variables excluding actual knowledge.

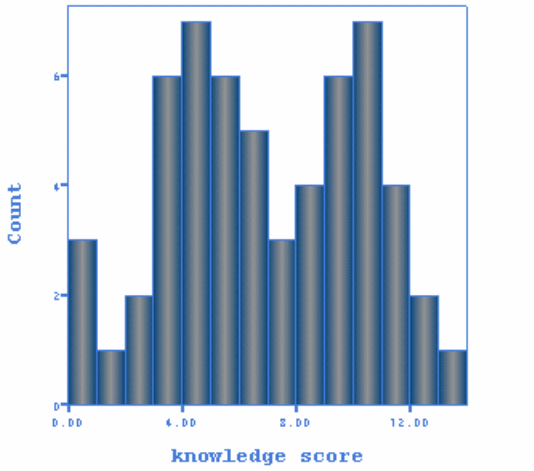

Figure 3. Frequency distribution of actual knowledge scores.

To investigate which variables had the greatest influence on risk perception we used a multiple linear regression analysis. This analysis was made for three dependent variables: risk for oneself, risk for others, and need for decontamination. Non-significant independent variables were excluded in a stepwise fashion. Risk perception for oneself is exclusively determined by emotional concern ($\beta_{standardized}$ = .62, t = 5.9, p < .001). The risk for others as presented in Table IV is determined by emotional concern ($\beta_{standardized}$ = .50, t = 4.4, p < .001), self-estimated knowledge ($\beta_{standardized}$ = -.27, t = -2.4, p < .05), and by exposure ($\beta_{standardized}$ = -.24, t = -2.1, p < .05). With $R^2_{adjusted}$ = .39, only a small part of the variance can be explained by the independent variables. The need for decontamination (see Table V) is determined by the risk perceived for others ($\beta_{standardized}$ = .21, t = 2.2, p < .05), a lower use of dissonance-reducing heuristics ($\beta_{standardized}$ = -.47, t = -5.1, p < .001), and thoughts about sustainability ($\beta_{standardized}$ = .43, t = 4.6, p < .001). With these three predictors, 57% of the variance can be explained.

Table IV. Summary of multiple linear regression analysis for variables predicting perceived risk for others (N = 57). $R^2_{adjusted}$= .322 for initial step; $R^2_{adjusted}$= .388 for final step.

	Standardized Beta	t	p
Final Step			
Emotional concern	.499	4.4	<.001
Self-estimated knowledge	-.274	-2.4	.019
Exposure	-.235	-2.1	.041
Initial Step			
Emotional concern	.401	3.1	.003
Self-estimated knowledge	-.241	-1.8	.082
Exposure	-.191	-1.6	.109
Knowledge	.148	1.2	.232
Sustainability	.086	.70	.487
Heuristics	-.061	-.47	.639

The control variables (e.g., age, gender, consumption of locally grown vegetables or fruits, and presence of children) did not have any significant influence on other variables. We also controlled for the age of children, but we still did not find any interrelation with other variables. The only exception was the control variable measuring the length of time residents had lived in Dornach, which correlated significantly with the use of dissonance-reducing heuristics (r = .34, p < 0.05) and the need for decontamination (r = -.46, p < .01). The longer people had resided in Dornach, the more they used dissonance-reducing heuristics and the less they expressed a need for decontamination.

Table V. Summary of multiple linear regression analysis for variables predicting need for decontamination ($N = 57$). $R^2_{adjusted} = .504$ for initial step; $R^2_{adjusted} = .573$ for final step.

	Standardized Beta	t	p
Final Step			
Heuristics	-.470	-5.1	<.001
Sustainability	.425	4.6	<.001
Risk for others	.214	2.2	.034
Initial Step			
Heuristics	-.443	-3.8	<.001
Sustainability	.404	3.8	<.001
Risk for others	.137	.94	.353
Risk for oneself	.07	.45	.657
Exposure	-.05	-.43	.668
Self-estimated knowledge	-.05	-.43	.670
Emotional concern	.05	.34	.737
Knowledge	.01	.10	.919

4.4. Discussion

Two interesting findings from the present research are that the high-exposure group and the low-exposure group do not differ in risk judgments for themselves and that people in the low-exposure group rated the risk for others more highly. Taken together, the implications are that the two exposure groups differ in their risk judgments. Fischhoff, Bostrom, and Jacobs Quadrel [(36)] have already pointed out that "asking people about risks to other people like themselves is not the same as asking them about their personal risk" (p. 994). The difference in judgments of the risks for others can be best explained using the following argumentation: Those who are in the low-exposure group cognize a group of others who are more exposed, whereas those living closer to the metal processing plant do not. While this may sound trivial, it is nevertheless noteworthy because the participants in the present study were unaware of their group membership and because the distance to the risk source was rather small (less than 2 km). The fact that both exposure groups similarly rated the risk for oneself could indicate a kind of self-regulation. That is, people are willing to accept a certain upper risk level for oneself. Above this level, however, people are no longer comfortable. Of course, this level varies individually, but because the two groups were comparable with respect to the socio-demographical variables, they achieved the same average.

The absent correlation between the presence of children, the consumption of local produce, or the duration of the exposure with the perceived risk could also be interpreted as a type of self-regulation. Objectively, children, people consuming local produce, and people who are exposed for longer periods of time are more at risk than are others. It is likely that people who are initially less concerned about the risks involved are more likely to consume or to continue consuming vegetables or fruits grown in their own garden or grown by local producers. Of course, by doing so they are increasing their risk. It seems to be crucial that the risk in

Dornach is caused by refuse dumps, which have been in existence for several decades; the longer someone has been living in the contaminated area the more likely it is that he or she uses dissonance-reducing heuristics. The correlation between these two variables is independent of the age of the participant. The stress of living on contaminated soil and of being at risk for years is argued to initiate self-regulation so as to reduce stress to an acceptable level [37-41]. Thereby, an emotion-focused coping was much more likely in the case of Dornach than a problem-focused coping [42, 43], because inhabitants of Dornach did neither have sufficient information about the risk of the soil contamination nor about the means of soil remediation.

As the results show, emotional concern plays a central role in personal risk perception. This is in line with other studies showing that emotional components [43] and personal concern [44] are essential in judgments of risk. Emotional concern had an influence on both risk measures and on judgments of the need for decontamination. As the link between the (objective) level of exposure and the (subjective) emotional concern is rather weak [45], the likelihood of a high level of emotional concern seems to depend more on other intervening variables.

Emotional concern correlated positively with thoughts about sustainability, a desire for additional information and negatively with self-estimated knowledge and the use of dissonance-reducing heuristics. Emotional concern thus seems to have some linkage with societal responsibility and knowledge/science based reasoning. Emotionally concerned people do not overweight their knowledge, i.e., they do not claim to know more about the problem than they do. Another interpretation for the negative correlation with self-estimated knowledge is that they underestimate their knowledge. Emotionally concerned people also use less simple heuristics. These heuristics seem to be a strategy for reducing emotional concern. People who cannot deal with negative emotions, such as worry or insecurity, are more prone to using dissonance-reducing heuristics. As people exposed to contamination cannot escape or reduce the objective risk as long as they live in Dornach, this dissonance is likely to be reduced using a cognitive strategy. As the application of the heuristics can be considered as means to cognitively devalue the risk. Thus, given the ongoing exposure of the inhabitants to the contaminated soil, which was not (yet) planned to be remediated by the public authorities, is consistent with the theory of cognitive dissonance [7, 9] as dissonance can be dissolved by downrating the environmental risk.

The different impact and role of actual knowledge and self-estimated knowledge on risk judgments for oneself and for others, for the need of decontamination and for cognitive processes is diverse. Inhabitants with self–estimated knowledge judged the risk for oneself and others, low and provided consequently also low rating on the need of decontamination. This high level of risk acceptance of these inhabitants is accompanied by a more frequent use of (erroneous) dissonance-reducing heuristics, a low need for information and low judgments of emotional concern. Contrarily, actual knowledge showed no significant correlation with any of these variables. These data suggest that people who think that they know all about and accepted the environmental risk seem to avert themselves by information processing that could refute their believe in the low environmental risk.

Also other authors have also observed this missing link between actual knowledge and risk perception [14]. Whereas the negative correlation we found between self-estimated knowledge and judgments of risk is consistent with some studies [4], other studies report a positive correlation between risk perception and self-estimated knowledge [46]. This nature of the correlation may depend on the type of risk and on whether the risk is known or unknown. If the risk is known, a high level of self-estimated knowledge may result in a feeling of control over the risk, thereby reducing the risk perception [21, 47, 48]. In line with this, Frewer et al. [49] found a

positive correlation between perceived knowledge and perceived control. On the other hand, if the risk is new and unknown, a high level self-estimated knowledge may represent a better awareness of the risk. This can be explained by the availability heuristic [50, 51]. Another explanation is that the increase in actual knowledge through being given new information increases participants' risk ratings [13]. The logic or the mechanism behind these differences may be similar to the one described above with respect to the dissonance-reducing heuristics. The high correlation between the use of dissonance-reducing heuristics and self-estimated knowledge suggests that people may see these heuristics as a type of knowledge. Moreover, actual knowledge does not correlate with the desire for additional information in contrast to self-estimated knowledge, which correlates negatively, and emotional concern, which correlates positively.

Another interpretation of the missing influence of the extent of actual knowledge on people's risk perception could be a failure in risk communication. Local authorities and other actors may have failed to communicate the risk and any important knowledge in an adequate manner. Due to this inadequate risk communication and the absence of knowledge about the situation (particularly the knowledge of how to deal with the situation) other factors, such as emotions and stress-reducing strategies, have begun to dominate most aspects of the risk perception process. Mental modeling [52] could potentially be an appropriate tool for application in this community. Additionally, greater and closer participation of inhabitants in the risk dialogue would certainly be advantageous.

The need for decontamination or willingness to act are conceived a consequence of negative states of risk acceptance. We postulate that an involuntary exposure to high risks is accompanied by the objective to get rid of it. The need for decontamination is positively related to risk perception, particularly to the risk people see for others, thoughts about sustainability, and negatively with dissonance-reducing heuristics. The correlation of the need of decontamination with risk perception is quite high. The influence of risk perception on people's desire for risk reduction has been empirically validated by many studies [53-55], but is sometimes also doubted and critically discussed [56-58].

From an environmental risk management and risk communication point of view it is interesting to study which perceived benefits affect risk acceptance. The data of this study suggest that people who include thoughts about sustainability and precaution issues in their judgments have a stronger need for decontamination. This influence of thoughts about sustainability is in line with findings of other studies [11, 13, 37]. On the other hand, the use of dissonance-reducing heuristics decreases the need for decontamination. This influence of dissonance-reducing heuristics on the need to do something about the risk has to be considered within the context of risk communication or prevention of risk-taking behavior. Dissonance-reducing heuristics may make people 'cognitively immune' to risk reduction arguments. Admittedly, the need for decontamination is also correlated with emotional concern, but in the regression analysis, emotional concern was not a significant predictor for decontamination. Its influence seems to be moderated by risk perception.

The present study is a good example of combining an environmental case study with basic psychological research using a quasi-experimental design. In contrast to rather descriptive and static approaches such as the psychometric paradigm [24, 44], we focused on the process of individual risk perception. We were able to identify some important variables. The correlations we found between our variables and the risk measurements are consistent with other studies and are not a new finding. However, our study investigated these variables in an integrated manner

so as to observe the relative importance of each as well as their interaction, and we did this in the context of a real-world case study [59]. Since we used rather holistic overall judgments as opposed to multifaceted scales and because our sample only consisted of 57 participants, a replication with another case would be advantageous.

The effect of exposure or how people deal with being exposed seems to be a complex topic. Based on the findings of our study, dissonance-reducing heuristics seem to be an important issue in risk communication. Furthermore, the dissemination of information on risk is no guarantee that the perceived risk will be judged appropriately. In this context, we consider the emotional impact to be central to risk perception. We further believe that emotional concern will go beyond a simple affect heuristic [60]. We thus suggest that emotional concern and its relation to risk perception and risk management, in particular to the willingness to act or to support soil remediation programs, should be stressed in future research. Thereby, the role of emotions could be further specified (e.g., positive and negative emotions). Also the conditions and effects of a problem-focused versus emotion-focussed coping with an environmental risk could be of major interest.

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5. Exposure, Emotional Concerns, and Information Processing in Environmental Risk Perception

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Abstract

Previous quasi-experimental studies compared judgments of exposed and non-exposed people on heavy metal contaminated sites. These studies identified relevant variables of risk perception on soil contamination such as exposure, emotional concerns, self-estimated knowledge, and the use of dissonance-reducing heuristics. The present study analyses the impact of these variables in an experimental "microworld" setting. 60 participants were confronted with heavy metal soil contamination. Depending upon experimental condition, participants provided risk judgments for different scenarios either in the role of an exposed layperson, a non-exposed layperson or an expert. Probability and harm were varied. The data analysis revealed that participants additively, as opposed to multiplicatively, integrated the information on harm and probability. Exposure had no direct influence on risk judgments. Emotional concern had a significant direct influence on risk judgments and significantly interacted with harm. Emotionally concerned subjects also displayed a more pronounced desire for additional information, used less dissonance reducing heuristics and were more likely to process information using an intuitive mode of thinking. As such, the intuitive mode of thinking and the analytic mode of thinking differed in the extent of their influence on risk judgments.

Key Words: Environmental risk, heavy metal contamination, risk perception, information integration, emotional concerns

5.1. INTRODUCTION

Since the work of Laplace[1], mathematical definitions of risk have basically included events with negative outcomes occurring with a certain probability. In addition to this approach, risk perception research has identified qualitative aspects such as voluntariness, controllability, or catastrophic potential[2] as being important. A risk source is perceived less risky if people are voluntarily exposed, feel as if they have control over the risk, or do not see the possibility of a catastrophe. Using a factor-analytic approach, Slovic[3,4] reduced these qualitative characteristics to the two main factors of "dread risk" and "unknown risk". The traditional psychometric paradigm is characterised by some severe weak methodological points. One is the problem of aggregating individual data and studying average profiles of risk perception[5,6]. Another is the factor-analytic approach, which does not reveal the cognitive processes underlying risk judgments. Given the fulfilment of certain prerequisites, factor analysis can be an appropriate method for reducing the universe of variables to a few dimensions but is still reveals little about the underlying psychological processes, functionality or even the goals of subjects. By the middle of the previous century Thurstone[7], a father of the factor analysis, already considered this procedure to be a tool for providing only a very first map of the investigation area.

Proponents of the psychometric approach argue that, in addition to probability and harm, qualitative and subjective components have to be incorporated in the study of risk perception[3,4]. Yet, if we wish to learn more about the processes involved in risk judgments, we need to go beyond the classical psychometric approach. One extension is to broaden the space of risk cognition[8] and to consider risk cognition as being an activity based on multiple cognitive representations and qualitatively different cognitive processes. According to Scholz & Tietje[8], representations of risk situations range from numerical representations[9] (e.g., statistics such as frequencies or measures of variance), through semantic aspects and representations (e.g., voluntariness, dread and episodic risk knowledge), to prototypical pictorial representations (e.g., roulette wheels or snowflakes linked to Laplace or Geometric probability). An interesting question in this context concerns the role these various elements play in the perception of environmental risk perception and how different information is integrated.

Previous research on probability judgments[10,11], decision making[12,13], and problem solving[14], suggests that it is reasonable to differentiate between an intuitive and an analytic mode of thinking. Each mode is characterised by different features of cognitive representations and different cognitive processes. These features can be measured; for example, when analysing think-aloud protocols[8]. Thus, three features (of ten) characterising analytic thinking are: (a) conscious information acquisition, selection, and processing, (b) sequential, linear, step-by-step, ordered cognitive activity and (c) high consciousness. In contrast, intuitive thinking features include: (a) preconscious information acquisition, (b) understanding through feeling and empathy, and (c) sudden, parallel processing of a global field of knowledge. A critical proposition of this research is that emotions elicit the mode of thought and, as such, a question investigated in this paper is the extent to which risk cognition is influenced by or interacts with the emotional state or dispositions of the agent.

The role of emotions in risk perception and decision making was the subject of intense investigation in the previous decade[15-23]. One of the main findings of this research was the positive correlation between worry or fear and risk measures. People who are worried about a certain risk provided higher risk ratings. Finucane et al.[24] labelled the influence of emotions on risk perception the affect heuristic. From our point of view, emotional impacts should neither be reduced to a global tendency nor to a simple heuristic. We rather think that there are complex

interactions between two systems: emotions and (risk) cognition. Emotional involvement has an influence on information processing as it was shown with the heuristic-systematic model[25,26] and on information processing underlying risk judgments[27].

According to Lerner & Keltner[16] not only worry or fear have an influence on risk judgments, but that also other emotions show. In our study we focus the investigation of negative emotional involvement on the process of environmental risk cognition. Some insights into the cognitive processes underlying individual risk perception have been gained in quasi-experimental studies on risk perception in the case of soil contamination in Dornach. Dornach, a medium-sized village near Basel in north-west Switzerland[28], served as a case in a ten-year research program investigating the assessment and perception of soil contamination[29-32]. Dornach has one of the highest levels of heavy metal contamination, especially cadmium, in Switzerland[33,31]. Comparative studies have shown that this concentration of cadmium could probably lead to negative health consequences in the long term[34,35]. Possible paths through which the absorption of heavy metal could occur include the consumption from locally cultivated vegetables, particular tuber plants such as celeriac, or the swallowing of soil, as is often the case with infants[36].

In two previous questionnaire-based studies[37,38] exposure, emotional concerns, self-estimated knowledge, and dissonance-reducing heuristics were shown to significantly affect risk judgments. For example, people with low exposure to soil contamination rated the risk for other inhabitants in Dornach to be higher than people with high exposure levels, whereas people in both groups rated the risk for oneself similar. Emotional concerns had a strong influence on the way people perceived the risk. The more people were emotionally involved, the higher they perceived the risk to be. Self-estimated knowledge, but not actual knowledge, influenced risk perception. The more participants claimed they knew about the problem the lower they perceived the risk to be. Participants who used dissonance-reducing heuristics were less emotionally concerned and did not see the need for decontamination. Dissonance-reducing heuristics were often comprised of rather weak arguments, which people used to reduce their cognitive dissonance[39] or worry. Such dissonance reduction is probably a type of trivialization[40].

The aforementioned variables of exposure, emotional concerns, self-estimated knowledge, and the use of dissonance-reducing heuristics, along with the way in which they were interrelated, provided some indication of the individual processes at work while people are judging a risk. However, what Weber et al.[37] and Grasmück and Scholz[38] could not examine in their questionnaire-based studies was the information processing of the participants: it could not be ascertained whether participants reasoned using a more intuitive or more analytic process. Moreover, there may have been other intervening variables that were unable to be controlled in the real-life situation. To determine whether or not the aforementioned variables are central to people's judgments of risk and to investigate these variables in a more controlled environment, we developed a computer-based microworld called Dornhausen. Within this microworld participants were confronted with different scenarios of soil contamination. In this computer simulation we modelled the real case of Dornach and manipulated those variables shown to be important in the previous questionnaire-based studies in Dornach.

In the case of heavy-metal contaminated soil, the personal health risk depends on the extent to which one is exposed. As the influence of exposure on risk perception was already of special interest due to work in previous studies by Weber et al.[37] and Grasmück and Scholz[38], it was decided to manipulate exposure an independent variable. Participants were allocated to

three groups: 1) an exposure group, which lived in Dornhausen in single-family houses with polluted soil, 2) a non exposure group, which lived in similar village nearby (Schoenwil) with no soil contamination, 3) an expert-group, taking on the role of external consultants.

We expected that the method of information processing would also play an important role. Thus, we included the variable mode of thought and distinguished between intuitive and analytic modes of thought[11]. The use of these concepts in this paper is consistent with the work by Petty & Caccioppo[41] or the heuristic–systematic model[25,42]. We assume that emotions such as fear and anxiety inhibit systematic, analytic information processing. In particular, we want to clarify and elaborate Trumbo's[27] findings on the relationship between the information processing within the heuristic–systematic model and between information processing and risk judgments.

Finally, we want to investigate the extent to which the basic components of risk information, harm and probability, are integrated[43] and whether and under which experimental conditions participants focus on only one of the two components. Thus, we systematically manipulated harm and probability[44,45]. The levels of the independent variable scenario are combinations of levels of harm and probability.

From the arguments and theoretical considerations mentioned above, three research questions can be formulated:

- How do exposure and emotional concern affect the risk judgments and how do these variables interact?
- Which influences do the two modes of thought (i.e., analytical versus intuitive thinking) have on the risk judgments?
- How do participants integrate probability and harm and in which ways do exposure and emotional concern affect the way participants integrate probability and harm?

Finally, as a follow up of the previous quasi-experimental study of Grasmück and Scholz[38], we will examine how knowledge components such as information seeking, desire for additional information, and dissonance reducing heuristics affect the risk judgments.

5.2. METHOD

5.2.1. The design of the study and the instrument

A computer environment has been developed. Participants had to change their place of residence at the beginning of the computer simulation. Depending on the test condition, they moved either to Dornhausen or to Schoenwil. They also had to make some decisions (e.g., whether or not they wanted to cultivate fruits or vegetables in their own garden). After having lived for a few years in their new home, participants were informed of the heavy metal soil contamination in Dornhausen by the local newspaper. The participants who had been living in Dornhausen were informed that they had been exposed for some years. For the non-exposed group living in Schoenwil there was no risk for oneself; Dornhausen was simply a village in the same political administrative entity. For the expert group, Dornhausen was geographically distant.

In a simulated discussion participants could converse with a colleague about the problem. The purpose was to better involve the participants in the situation. Additionally, some dissonance-reducing arguments were offered during these discussions. For example, often

mentioned was a man, who lived his whole life in close proximity to the metal processing plant, which was the source of the contamination. This man regularly ate vegetables from his own garden, was always very healthy, and died at a very old age.

Participants had the possibility of obtaining information about the Dornach case by pressing certain buttons. This information was taken from the real case of Dornach (e.g., the type of pollution). They could read a letter from the municipal council, a letter from the plant's board of directors, a statement from experts, a flyer from an environment organisation, or a newspaper article. The information was formulated in a neutral manner so as to not affect the judgments of participants or lead them in a certain direction. The amount of information gained and the time a participant invested in obtaining the information was used to assess the variable information seeking.

The experiment followed the principles of functional measurement design[44]. Participants were informed that there were different possible scenarios of the extent to which there could be a risk in Dornhausen. There were three possible levels of probability and three possible levels of harm. Thus, participants were required to judge 9 scenarios (see Table I). Participants had to decide for each scenario how much money the community should spend on decontamination. The more money spent, the better the soil could be cleaned. Thus, the amount of money participants chose to spend constituted their judgment of risk in each scenario. The maximal amount the community could spend was CHF 10 000 000. Participants of the exposed group and of the non-exposed group lived in the same political entity, but in different villages. The expert group was the only group to not be directly affected by the decision. In contrast to the original specification of the functional measurement approach, we did not work with repeated measurements. Due to a lack of time and because the situation should be rather clear to the participants, judgments for each combination of probability and harm were only measured once.

Table I. 9 Scenarios, for which participants had to make them risk judgments, as a function of harm and probability

	Low probability 1:1 000 000	Medium probability 1:100 000	High probability 1:10 000
Low harm: Environmental problems	Scenario 1	Scenario 2	Scenario 3
Medium harm: Environmental problems and allergies	Scenario 4	Scenario 5	Scenario 6
High harm: Environmental problems, allergies, and kidney malfunctions	Scenario 7	Scenario 8	Scenario 9

Three kinds of harm were differentiated. The least dangerous variant involved environmental problems resulting from the soil contamination. The medium hazardous variant involved an ecological problem and allergies. The most hazardous variant involved an ecological problem, allergies, and kidney malfunctions. Next to each harm variant's verbal description was a corresponding illustration. Due to the problems most people have in understanding or dealing with numerical representations of the probabilities of risks[46], we added some additional information. Apart from the numerical representation, the probabilities were described verbally, compared with other sources of risk with a similar probability, and graphically demonstrated by manipulating the size of the picture used for each harm variant.

The idea behind this type of measurement was to investigate the way in which the different groups integrate information about probability and harm. Do they integrate this information through multiplication? If so, then the main effects of probability and harm and their interaction should all be significant in an ANOVA. If they integrate the information through addition, then only the main effects of probability and harm should be significant. Probably, they neither integrate the information by multiplication nor by addition, but they focus on one single information, and then only one main effect gets significant[44].

Upon providing their risk ratings, participants had to answer several questions regarding their interaction with the microworld. These questions were integrated in the microworld program. Their answers to certain items would provide an indication of whether they processed the information and provided the risk ratings rather intuitively (3 items; e.g., "Did you make your judgments intuitively?"), or analytically (10 items; e.g., "Did you carefully examine the available information?"). The items were constructed on the basis of work by Scholz[11]. The use of dissonance-reducing heuristics was assessed with 5 items (e.g., In Eastern Europe the situation is much worse), with which participants had to rate their level of agreement and the extent to which they took it into their consideration. These statements were collected in the real-life case of Dornach[37,38]. The desire for further information about soil contamination was assessed using a single holistic judgment. All items were assessed using a bipolar continuous scale, with values between 0 and 1. In order to move to the next screen, all items had to be answered.

To assess the change in emotional concern caused by the risk situation, we compared ratings participants made before the microworld study with ratings they made after their risk judgments in the microworld. Participants had to fill out a questionnaire before the microworld study[47], where they had to give their judgments to different risk sources and different risk characteristics, similar to those of the psychometric paradigm[3]. One of the items asked the personal emotional concern regarding the risk of heavy-metal soil contamination. This item were included in the microworld program. In addition, we included a scale of emotional demarcation in the questionnaire[48], which is expected to be a personal trait. This scale is comprised of 7 items (e.g., The problems of other people are affecting my mood).

5.2.2. Participants

60 Swiss high-school students (Kantonsschule) participated in our study. The average age of the participants was $M = 17.8$ years ($min = 16$, $max = 21$). The groups were similar in terms of sex-distribution (by design) and in terms of age (both between and within groups for the two sexes; see Table II). Participants were randomly assigned to the groups, the only restriction being that each group consist of 12 female and 8 male students. 19 (24%) participants

were smokers. There were no significant statistical differences between the three groups for any of these data.

Table II. Description of the samples

Experimental group	Exposed lay persons	Non-exposed lay persons	Experts
Sample	$N = 20$ (8 male, 12 female)	$N = 20$ (8 male, 12 female)	$N = 20$ (8 male, 12 female)
Age (in years)	$M = 17.7$ (male = 17.8, female = 17.6)	$M = 18.0$ (male = 18.0, female = 18.0)	$M = 17.8$ (male = 17.4, female = 18.1)
	$SD = 0.93$	$SD = 1.05$	$SD = 1.07$

5.2.3. Procedure

Participants filled in a questionnaire approximately two weeks prior to the experiment. For each different risk source, they were to rate their level of emotional concern. The emotional concern values for soil contamination were taken as the base or reference value.

The investigation was run in computer rooms with each student having their own computer. Participants had sufficient time to complete all tasks, with the experiment taking between 30 and 65 minutes to complete. Participants were unaware of the procedure or the nature of experimental design and any manipulations during the data collection.

5.3. RESULTS

In order to examine the extent to which the independent variable exposure (low vs. medium vs. high) had an effect on emotional concern, we compared levels of emotional concern measured using a questionnaire prior to the experiment with levels of emotional concern reported after having interacted with the microworld (time of measurement: before vs. after microworld interaction). Both emotional concern scores were z-transformed. Gender was also included in the repeated measurements ANOVA as an independent variable.

Table III: ANOVA table with emotional concern as dependent variable and exposure, gender and time of measurement as independent variables ($N_{exposed} = 20$, $N_{non\text{-}exposed} = 20$, $N_{Expert} = 20$)

Source	Df	F	Sig.
Exposure	2	0.44	0.645
Gender	1	0.04	0.852
Change in Emotional Concern (before vs. within the experiment)	1	0.18	0.673
Exposure * Gender	2	0.12	0.887
Exposure * Change in Emotional Concern	2	2.4	0.098
Gender * Change in Emotional Concern	1	4.5	0.039
Exposure * Gender * Change in Emotional Concern	2	3.2	0.049

Exposure and gender had no direct influence on emotional concern. Despite the absence of any main effects, there was an interaction between gender and time of measurement ($N = 60$, $df = 1$, $F = 4.5$, $p < 0.05$) and a three-way interaction between exposure, gender and time of measurement ($N = 60$, $df = 2$, $F = 3.2$, $p < 0.05$). Although gender did not have a direct effect on emotional concern ($M_{male} = 0.54$, $M_{female} = 0.62$), male but not female participants differed in their change in emotional concern in dependency of the fact if they are exposed or not as we can see in Figure 1. Non-exposed male showed even a decrease of emotional concern. Female participants were in the same way emotional concerned however they are exposed or not. In the role of an expert male and female participants did not show notable changes in the degree of emotional concern.

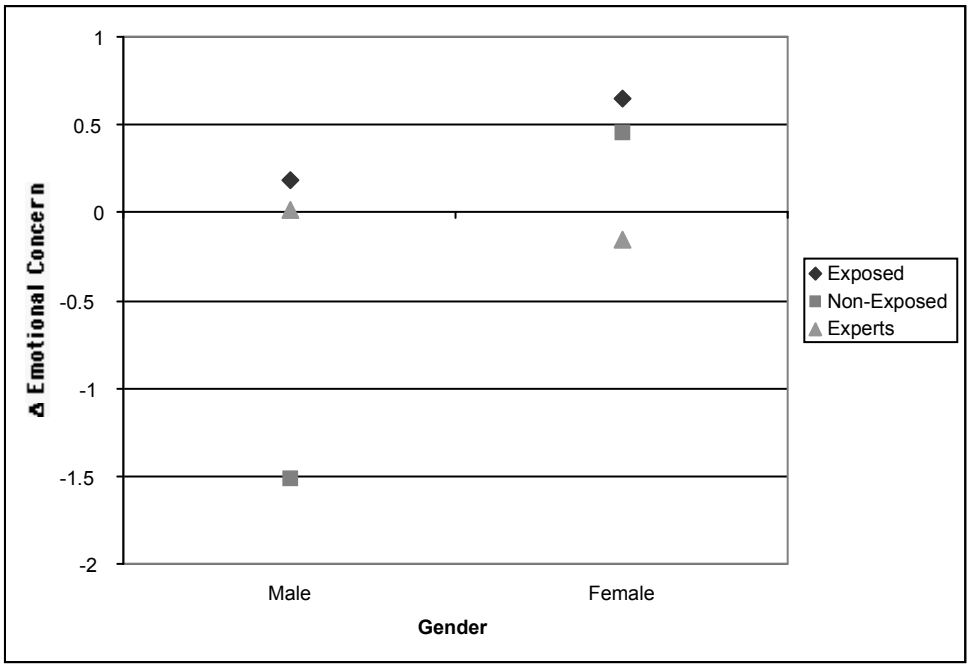

Figure 1. Relationship between exposure and emotional concern as a function of gender. The Figure shows means for differences in emotional concern in comparison to a pre-test rating.

Examination of the risk judgments using exposure, probability, and harm, as independent variables (see Table IV) reveals that there is no significant main effect of exposure. The fact that significant main effects were obtained for probability ($N = 60$, $df = 2$, $F = 17.8$, $p < 0.001$) and for harm ($N = 60$, $df = 2$, $F = 36.4$, $p < 0.001$), with no significant interaction effect between these two independent variable ($N = 60$, $df = 4$, $F = 0.16$, $p = 0.96$), indicates that integrated the information by addition and not by multiplication (see Figure 2). Whereas participants in the exposed group differentiated more between the various levels of harm, experts took the level of probability more into their account when making their risk judgments. However, these tendencies were not significant.

Table IV: ANOVA table for the risk judgments as a function of harm, probability and exposure ($N_{exposed} = 20$, $N_{non\text{-}exposed} = 20$, $N_{Expert} = 20$)

Source	Df	F	Sig.
Harm	2	36.4	< 0.001
Probability	2	17.8	< 0.001
Exposure	2	0.54	0.582
Harm * Probability	4	0.16	0.960
Harm * Exposure	4	1.6	0.186
Probability * Exposure	4	0.24	0.917
Harm * Probability * Exposure	8	0.11	0.999

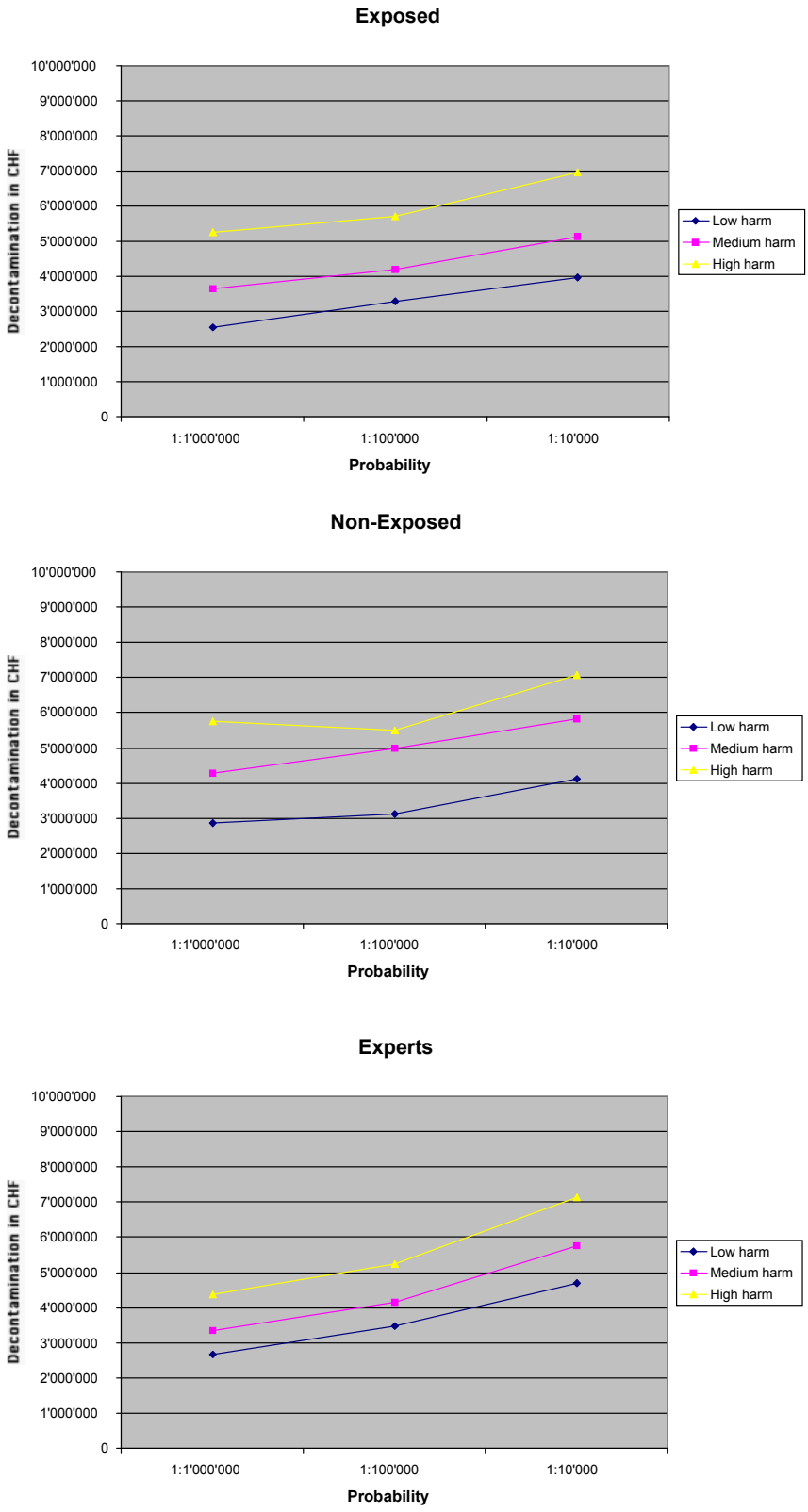

Figure 2. Risk judgments for the three different exposure groups

To investigate the influence of emotional concern on the risk judgments we conducted an ANOVA with harm (low vs. medium vs. high), probability (low vs. medium vs. high), and emotional concern as independent variables (see Table V). As emotional concern was measured on a bipolar continuous scale from 0 to 1, participants were first split into three groups of equal size varying in terms of their level of emotional concern: low (0 – 0.5), medium (0.51 – 0.69), and high (0.7 – 1). Finally, we also compared the rating for emotional concern participants gave in the first questionnaire (i.e., before interacting with microworld) with the rating they gave within the microworld (i.e., after interacting with the microworld)..

Emotional concern had a direct and highly significant effect on the risk judgments as measured by the amount of money spent on decontamination ($N = 60$, $df = 2$, $F = 6.6$, $p < 0.01$). The group comprised of participants with high levels of emotional concern were more willing to pay for decontamination than the other two groups did. There was also an interaction between emotional concern and harm ($N = 60$, $df = 4$, $F = 2.5$, $p < 0.05$). The risk judgments of participants with high levels of emotional concern were influenced by levels of harm to a larger extent than was the case for the remaining two emotional concern groups. The main effects of harm and probability were also significant in this analysis and can be interpreted in the same way as mentioned above.

Table V: ANOVA table for the risk judgments as a function of harm, probability and emotional concern ($N_{lowEC} = 20$, $N_{mediumEC} = 20$, $N_{highEC} = 20$)

Source	Df	F	Sig.
Harm	2	37.5	< 0.001
Probability	2	18.4	< 0.001
Emotional Concern	2	6.6	0.001
Harm * Probability	4	0.16	0.957
Harm * Emotional Concern	4	2.5	0.043
Probability * Emotional Concern	4	0.37	0.834
Harm * Probability * Emotional Concern	8	0.04	1.000

The homogeneity of the two sets of items measuring the two distinct modes of thought was tested using a reliability analysis. *Cronbach's alpha* for the items indexing the intuitive mode of thought was 0.71; for the items indexing the analytic mode of thought *Cronbach's alpha* was 0.78. After building a score participants were split into three equal sized groups each.

Table VI: Means and ANOVA with risk judgments as dependent variable and extent of adoption of the intuitive mode of thought as independent variable

	Intuitive mode of thought			ANOVA	
Variable	low	medium	high	F	p
Risk judgments in CHF	3,562,000	4,843,000	5,476,000	14.79	< 0.001

Table VII: Means and ANOVA with risk judgments as dependent variable and extent of adoption of the analytic mode of thought as independent variable

	Analytic mode of thought			ANOVA	
Variable	low	medium	high	F	p
Risk judgments in CHF	3,703,000	5,615,000	4,563,000	14.23	< 0.001

The extent to which an intuitive mode of thought was adopted directly influenced risk judgments ($N = 60$, $df = 2$, $F = 14.8$, $p < 0.001$; see Table VI). This influence was linear (M_{low} = 3,562,000, M_{medium} = 4,843,000, M_{high} = 5,476,000) such that the more participants adopted an intuitive mode of thought the more they adopted risk-reducing behaviour. Since we have already examined the effects of harm and probability and since there were no interaction effects between either mode of thought and harm or probability, we only report the effect of the variable mode of thought in Table VI and VII. The extent to which the analytic mode of thought was adopted also had a main effect ($N = 60$, $df = 2$, $F = 14.2$, $p < 0.001$; see Table VII). Examining the mean for each group reveals that an inverted U-shaped function is the best fit for the data (M_{low} = 3'703'000, M_{medium} = 5'615'000, M_{high} = 4'563'000). Participants who moderately adopted an analytical mode of thought exhibited the most risk-reducing behaviour. Consistent with this, curve estimation using a regression analysis indicated that a quadratic function was more appropriate ($F = 3.9$, $p = 0.02$).

Table VIII: Correlations between the two modes of thought and other variables (N = 60).

	Mode of thought	
Variable	Intuitive	Analytic
Wish for further information	0.30*	0.15
Information-seeking	0.13	0.38**
Emotional concern	0.48**	0.22
Dissonance-reducing heuristics	-0.09	-0.02

Note: Correlation with ** is significant at the 0.01 level (2-tailed). Correlation with * is significant at the 0.05 level (2-tailed)

The two modes of thought were slightly correlated, $r = 0.28$, $p < 0.05$. As seen in Table VIII, whereas the intuitive mode of thought was correlated with the expressed wish for further information ($r = 0.30$, $p < 0.05$) but not with the time the spent on information-seeking ($r = 0.15$, ns), the analytic mode of thought was correlated with the time the spent on information-seeking ($r = 0.38$, $p < 0.01$) but not with the expressed wish for further information ($r = 0.13$, ns). The intuitive mode of thought was correlated with emotional concern ($r = 0.48$, $p < 0.01$). The variable dissonance-reducing heuristics were split into three equal sized groups: low (0 – 0.27), medium (0.28 – 0.52), and high (0.53 – 1). The use of dissonance-reducing was not related with either mode of thought, but was related to emotional concern. The more people were emotionally concerned the more they used dissonance-reducing heuristics (see Table IX). Emotional concern correlated negatively with emotional demarcation ($r = -0.37$, $p < 0.01$).

Tab. IX: Means and ANOVA with dissonance-reducing heuristics as independent variable and emotional concern as dependent variable

	Dissonance-reducing heuristics			ANOVA	
Variable	low	medium	high	F	p
Emotional concern	0.2899	0.5019	0.4333	4.280	0.019

5.4. DISCUSSION

So as to improve the understanding of individual processes involved when dealing with risks, we confronted participants with the risk of heavy metal contaminated soil. Participants judged various alternatives, which were systematically varied with regard to probability and harm. The reported study also examined variables such as exposure, emotional concern, and the use of dissonance reducing heuristics, which previous research had demonstrated to be important in people's risk perception in a real-life case study of a site contaminated with heavy metals[38]. We used a computer simulation to test these variables in an experimental and controlled environment. Exposure was the key variable in our experimental design.

Exposure did not directly influence on the risk judgments. We assume that the influence of exposure on risk judgments is mediated by emotional concern, whereby the effect is carried by variables such as gender and the use of dissonance reducing heuristics. While exposed male participants are more emotionally concerned then non-exposed, female participants are emotionally involved weather they are exposed on them own or someone else.

In Marks and Winterfeldt's[49] study, exposure was positively correlated with perceived risk. Why, then, did exposure not have a significant effect on risk judgments in our investigation? In Marks & Winterfeldt's study participants were not living with the risk as it was the case in Dornach or in our computer simulation. Rather, they had to judge the risk given a certain probability of being exposed in the future. Thus, to prevent the possibility of exposure, people judged the risk as being higher; an expression of the "not in my backyard" phenomenon. The situation in Dornach or in the Dornhausen microworld is different: people are already living on contaminated soil and have been aware of the problem for some time. People probably try to reduce their feelings of worry or fear by using dissonance-reducing heuristics. Of course, some people do not share these feelings or worry or fear and are less irritated about the situation. The individual level of emotional involvement, is likely to affect the of use dissonance-reducing heuristics.

The interaction effect of gender, exposure, and emotional concern probably can also help to explain why in some studies there is a gender difference in risk perception[50] and in some studies not[51]. In situations where people are exposed male and female judge the risk the same way. When people have to judge a risk they are not in charge with, then women perceive the risk higher then men do.

In contrast to exposure, emotional concern had a strong direct influence on the risk judgment. The more people were emotionally concerned the higher they rated the risk. People higher in emotional concern also paid more attention to the nature of the consequences and focused their risk-reducing efforts on the alternative with the highest level of harm.

Emotional concern is also related to other variables. People with high levels of emotional concern used more dissonance-reducing heuristics. These rather weak arguments were obviously more necessary when people were more emotionally involved. This positive correlation stands in contrast to the results of Grasmück and Scholz[38], who found a negative correlation. This difference in findings can be explained by explicitly considering the timeline of the risk and adopting a dynamic approach. In our study, participants were confronted for the first time with the problem while participants in Grasmück and Scholz's study had been familiar with the problem for years. As people had been aware of the contamination for many years, their emotional concern had presumably already been reduced by the use of such heuristics[52]. In a situation where people are confronted with a new risk, people with higher emotional concerns are more likely to use dissonance-reducing heuristics. In a situation where people have already

been living with a risk for a long time, like in the case of Dornach, the cognitive structure of the heuristics gets consolidated, which lowers emotional concerns permanently and determines risk judgments. In conclusion, these simple heuristics or arguments seem to be a strategy by which to reduce emotional concern. People who can not deal with their negative emotions, probably feeling afraid or insecure, are more disposed to use dissonance-reducing heuristics.

Examining the integration of information about probability and harm it can clearly be seen that people were additively and not multiplicatively, integrating this information. In an ANOVA, while both had main effects on risk judgments, no interaction between these two information sources was observed[44]. Examination of the distributions of money allocations (i.e., risk judgments) rules out the possibility a ceiling effect. Additively integrating information concerning probability and harm, as opposed to multiplicatively doing so, stands in contrast to normative solutions and to the empirical findings of Anderson and Shanteau[53] in the context of SEU-Theory. The naturalistic, complex environment of the microworld may have encouraged this kind of integration among participants. It is probably the case that the negative cognitive framing lead to people using the simpler, additive integration. Additionally, as mentioned above, the greater the emotional concern of people the more they focused on the component of harm.

Emotional concern is positively correlated with the extent to which one adopts an intuitive mode of thought. As for emotional concern, an intuitive mode of thought increases the perceived risk. On the other hand, adopting an analytic mode of thought has an inverted U-shaped function with risk judgments. Participants with moderate levels of adoption of the analytic mode of thought were more likely to show risk-reducing behaviour. A potential explanation is as follows. In general, the analytic and the intuitive modes of thought do not exclude each other. They are two independent but partly correlated dimensions. If someone pays little attention to the risk situation, then that person judges the risk using low levels of intuitive and analytic thought; this person simply does not want to think about the risk situation. Thus, risk ratings or the risk-reducing behaviour for low levels of adoption of the intuitive and analytic modes of thought are low. The more the person is involved in the case, the more that person adopts an analytical and intuitive mode of thought. Yet this co-variance works only up to a medium level. Due to limited cognitive capacity, a person cannot adopt both modes of thought to a high extent. If a person is highly emotionally involved, then that person is also likely to have adopted an intuitive mode of thought to a great extent and cannot do likewise for the analytic mode of thought. People with a high level of intuitive thought judge the risk to be higher, whereas people with a high level of analytic thought are ‘rational’ and judge the risk to be moderate.

Putting all the pieces together we can formulate the model shown in Figure 3. Exposure does not have a direct influence on risk judgments. Exposure may increase emotional concern in conjunction with the level of the emotional demarcation of the person; females, for example, are in general more empathic[48,54,55] and are therefore more likely to be emotionally involved even when they are not exposed. Each individual has a certain level or threshold value of emotional involvement or worry that they can support or accept. If the emotional involvement exceeds that threshold then the person is likely to use dissonance-reducing heuristics. These heuristics, over time, gradually decrease a person’s emotional involvement. This gradual, delayed decrease, is the reason why an initial positive correlation between emotional concern and dissonance-reducing heuristics becomes a negative one after a certain period time as was the case in

Dornach. At the beginning, emotions dominate the process of making risk judgments; with time the cognitive structure of the heuristics becomes stronger and determines the risk judgments.

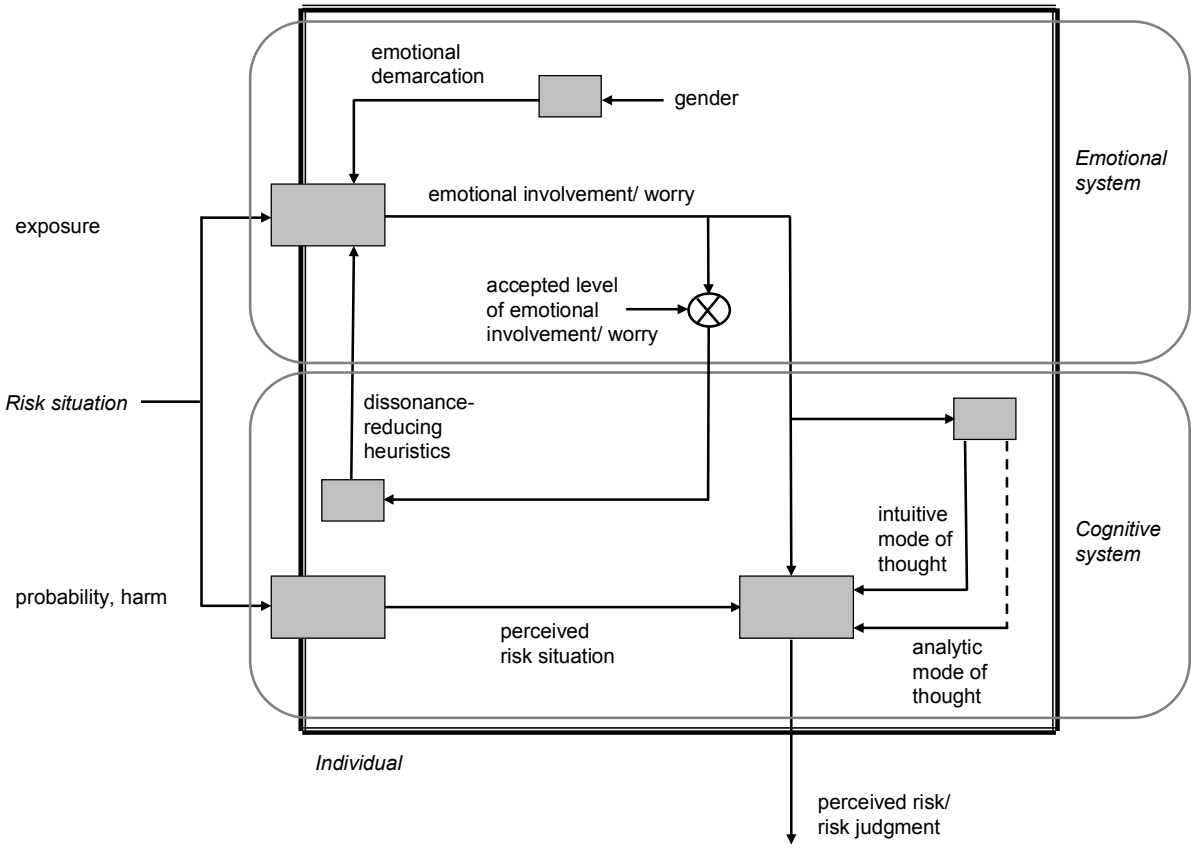

Figure 3. Model of the postulated relationship

Emotional involvement or concern has a direct influence on risk judgments and an indirect influence through the different modes of thought. A high degree of emotional involvement increases the perceived risk and leads to a greater focus on the component of harm. Adoption of the intuitive mode of thought has a linear positive correlation with risk judgments and risk-reducing behaviour. The analytic mode of thought has an inverted U-shaped relationship, with people being most motivated to do something against the risk at moderate levels of analytic thought. While we could not establish a significant relationship between emotional involvement and adoption of the analytic mode of thought in our study, we suppose that the relationship is also an inverted U-shape. According to the Yerkes-Dodson rule[56], people are more likely adopt an analytic mode of thought when they have a moderate level of emotional involvement. Our study involved a low-risk with possible effects only expected on a long-term basis. This was probably the reason why participants were not very highly emotionally involved and, thus, the highest values in emotional concern were only in a medium range.

Comparing our results with the results of previous studies in Dornach[37,38] reveals that the main findings, such as the influence of emotional concern on risk perception, could be replicated. Even contradictory results provided a hint of how the dynamic of these individual processes might work. This combination of quasi-experimental questionnaire-based studies in a real-life situation with the modelling of the risk situation and the use of an experimental design in a computer-based environment is, of course, a rather time-consuming but, in our point of view, promising methodological approach. However, this follow-up study should be understood as an exploratory pilot study; the sample was relatively small, the results should be better replicated, and our scales could also be improved.

We have provided a very interesting view of the individual processes underlying risk judgments. Emotional concerns have a strong influence on risk judgments. Possible effects of exposure on risk judgments may be moderated by emotional concern and by the interaction between gender and emotional concern or emotional demarcation and concern. The use of dissonance-reducing heuristics is a way to reduce the level of emotional concern. Whereas the extent of adoption of an intuitive mode of thought has a linear relation with risk-reducing behaviour, the extent of adoption of an analytic mode of thought has an inverted U-shaped relation. The generalisability of our results to other types of risk situation has to be tested. The emotional impacts on risk judgments could vary depending on the type of emotion[16] and on the interaction with the cognitive system[15]. Future research should continue to follow and adopt a dynamic and integrated approach so as to gain a better understanding of individual risk perception and risk judgments.

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6. Conclusions and Outlook

The starting point of the project was the real-life case of Dornach. We wanted to know how people are perceiving the risk of heavy metal contaminated soil. Thereby, exposure was from special interest, because the related health risk depends on the extent of ones exposure. Personal exposure was a relevant characteristic in the studies of Sclovic et al. (1980, 85), which should increase the perceived risk. Also Marks & Von Winterfeldt (1984) postulated a positive correlation between exposure and perceived risk, which they labelled the 'not in my backyard'-effect. In our studies exposure had not a direct influence on the risk judgements. I think that exposure has only an effect on risk judgements, if they are mediated by the emotional concern. In general, exposure increases the emotional concern. Emotional concern on its side has a very strong influence on the risk perception. The higher the emotional concern is, i.e. the more one is worried or afraid, the higher is the perceived risk. But there are two intervening factors which can cover up the influence of exposure on emotional concern. Firstly, people with a strong emotional demarcation are 'immune' to exposure effects. Particularly, females have in general a lower emotional demarcation (Figner & Grasmück, 1999), i.e. they are more empathetic (Bichof-Köhler, 1989). Thus, females are emotionally involved even if they are not directly exposed. This exposure - gender interaction can probably help to explain why some studies (Flynn, Slovic & Mertz, 1994) find a gender difference in the risk perception, whereas other studies do not . (Fontaine & Smith, 1995) or just under certain circumstances (Greenberg & Schneider, 1995). Secondly, I suppose for emotional concern. If the emotional concern, worry or fear, is permanently above this individual acceptance level, the individual will start to use dissonance-reducing heuristics, to get rid of these unpleasant feelings. I think there might be significant individual differences in this level. Some people can deal better with dissonance and unpleasant emotions, other people can not support them and are more likely to use dissonance-reducing heuristics. This process might explain why in the case of Dornach, where people have been exposed to the risk for many years, we do not find the clear effects Marks & Von Winterfeldt (1984) found. Participants in their study had to judge a hypothetical future risk.

A very interesting finding is also the change of the correlation for some couples of variables, i.e. the direction of the correlation. In study 3 the correlation between emotional concern and dissonance-reducing heuristics was negative, whereas in study 4 this correlation was positive. A change like this is typical for complex dynamic systems and can be explained by the feedback loop via individual acceptance level for emotional input and the use of dissonance-reducing heuristics. In addition, the negative correlation we found between self-estimated knowledge and the perceived risk in study 3 is in contradiction to some studies, which found a positive correlation (Maderthaner et al., 1978). This change of correlation indicates a dynamic process as well. If a risk is new, a higher self-estimated knowledge stands for a higher risk awareness, which increases the risk perception. If a risk is old and known, a higher self-estimated knowledge can give a feeling of control, which decreases the perceived risk.

According to the results of study 4 participants are integrating probability and harm rather by addition than by multiplication, a ceiling effect can be excluded. This is in contradiction to the normative solution (see also Anderson & Shanteau, 1970). Already at around 13 years most children do proportionally integrate probability and harm (Falk & Wilkening, 1998). But the fact that most of the participants in our study integrated additively could be explained by the naturalistic setting. People do integrate the information in a complex situation as it is the case in Dornach with simple rules. Nevertheless, exposed people show a

tendency to differentiate the harm components. They look at what the differences are of the probable damage potentials and pay more attention to a risk with higher damage potential and less attention to a risk with a lower damage potential. However, this tendency is not significant. On the other hand, a clear result was that participants with higher values for emotional concern rated the risk higher in general, and focussed more on the harm components.

In contrast to the original functional measurement design we did not work with repeated measurements, the lack of time was the main reason for this. Some participants needed more than 1 hour to complete the experiment. The pre-tests showed that the participants understood both the design and the scenarios well and did not have any major problems reaching their judgements. The setting was rather naturalistic. Participants also had to give their judgements for a second risk situation, the exposure to a cellular phone base station. But because the article was already very complex, we did not assess all the other variables with the cellular phone scenarios. In general, the results were similar. The advantage of a repeated measurement is the fact that you have reliable risk variables for each individual. To have also measured at the individual level, I developed some algorithms. These measures were not described in the article, but showed similar results than at the group level. Advantages of these algorithms are that you have continuos and not nominal scales. Thus, you know the degree to which, and how far someone integrate the information by addition or multiplication, or is focussing on one component, and you can correlate it with other variables. Moreover, the visual check for results indicate a possible multiplication is not necessary.

It has also to be considered that risk perception and risk acceptance (verbal and behavioural) are determined by different variables. Risk perception is predicted exclusively or mainly by emotional concern. Risk acceptance is in addition predicted by additional variables such as benefit.

Future research should focus on psychological processes on an individual level, particularly to dynamic processes. Emotions are playing an important role, it could be further investigated what emotions play what role in the risk perception process. The emotions, which are involved in risk perception, probably could be set in relation to the individual motivational profile of a person. The missing link between actual knowledge and risk perception, at least in the case of Dornach, and the exclusive role of emotional concern to increase the desire for further information, should be considered in the risk communication context. In fact, results of the risk perception research should be more considered in the risk communication context in general.

From the methodological point of view, the combination of quasi-experimental design in a real-life naturalistic setting followed by an experimental design, which investigates the variables in a computer simulation, seem to be a good and beneficial approach. The real-life context guarantees a higher relevance and external validity of the results. The Microworld allowed an objective data collection and the relevant variables could be systematically varied. Of course, it was explorative and the only major disadvantage was the vast amount of work such an approach demands (e.g., travelling to Dornach, programming a Microworld).

In my view, this project has some relevant implications for the theory of risk perception and the used methodology as well. But this project not only had an impact on the scientific study, but it also had some relevance for Dornach itself. First, we wrote the questionnaire for the first study in co-operation with the members of the town council in Dornach. Second, we offered a case study book about Dornach to the general public. Third, we sent the results of the studies to the participants and we also presented them to the town council. We gained a good

understanding of the situation in Dornach. The heavy-metal soil contamination was compared to other risk sources and described by some characteristics/ factors. Thus, we have an idea how this risk source is perceived.

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8. Abstract

The goal of the project was to investigate the psychological processes of risk perception on an individual level. Thereby, the case of Dornach gave the applied context. Dornach is a village near Basel, where the soil is widely contaminated with heavy-metals. Because the personal health risk of soil contamination depends highly on the extent one is exposed, exposure was a crucial variable in our experimental designs. Four studies were derived in a timely sequence and the later studies were based on the results of the previous ones. In so far, the project had an explorative character.

In the first quasi-experimental and questionnaire based study (N= 80), the risk perception of exposed inhabitants of Dornach was compared with the risk perception of people from comparable villages, but where there is no soil contamination. Whereas exposed persons judged the risk at their residence higher than non-exposed people did, exposed persons judged the risk of heavy metal soil contamination in general lower than non-exposed persons. Heavy metal soil contamination was compared to other risk sources and according to a factor analysis it was perceived indifferently regarding dread, its uncontrollability was estimated as medium, and its catastrophic potential as low. Sustainability, like the prevention of harm for future generations, were highly correlated with the acceptance of the use of bioremediation methods on the people's residential area. During this first study, we had intensive contact with some inhabitants of Dornach and we could identify some relevant additional variables such as the use of dissonance-reducing heuristics or emotional involvement, which we wanted to include in the following studies.

In the second questionnaire study (N=112), similar to those of the psychometric paradigm, we compared the results of a classical factor analysis, which is aggregated over participants, with an individual factor analysis, which is aggregated over risk sources. Heavy metal soil contamination was compared with other ultra-low-risks such as using cellular phones, consumption of beef (BSE), and genetically modified food, and with other classical risks like traffic, smoking, and nuclear power. Factor analysis on the individual level shows that the factor dread, which we found in the classical factor analysis, was split in the two factors of emotional concern (Factor 1) and damage potential (Factor 2). Benefit was a third factor. Regression analysis shows that the factor emotional concern is an essential predictor for the perceived risk, the risk acceptance, and the desire for additional information. Whereas emotional concern and the potential damage are significant predictors of the perceived risk, emotional concern and benefit are the predictors for risk acceptance.

The third quasi-experimental, questionnaire-based study was again conducted in the community of Dornach (N=57). Because the level of contamination varies with the distance from the source of the contamination, we compared the perception of risk of heavy metal contaminated soil by high-exposed and low-exposed inhabitants. Both groups judged the risk for themselves similarly whereas the low-exposure group, when compared to the high-exposure group, perceived the risk for other affected people living in their community to be higher. Besides this exposure effect, risk perception is mainly determined by emotional concerns. The extent of actual knowledge about the risk had no influence, unlike self-estimated knowledge. Judgments on the need for decontamination are determined by risk perception, less application of dissonance-reducing heuristics, and commitment to sustainability. The desire for additional information is not affected by missing knowledge but is affected by emotional concerns.

In the forth study we analyzed the impact of the variables, which were identified as relevant in the previous studies, by an experimental computer-based design (*N*=60). In this "Microworld" we modeled the case of Dornach and participants had to provide risk judgments for different scenarios either in the role of an exposed layperson, a non-exposed layperson or an expert. Probability and harm were varied. Thereby, the participants integrated the information on harm and probability by addition and not by multiplication. Exposure had no direct influence on the risk judgments. Emotional concern had a significant direct influence on the risk judgments and showed interactions with harm. Emotional concerned subjects had also a more pronounced desire for additional information, used less dissonance reducing heuristics and were more likely to be processing in the intuitive mode of thinking. Thereby, the intuitive mode of thinking and the analytic mode of thinking differed in their influence on the risk judgements.

Finally, based on the results of the four studies a model of individual risk perception and judgements was developed. Thereby, emotional concern played a crucial role. On the one hand, it increases the perceived risk. On the other hand, if the emotional involvement, worry or fear, is over an individual accepted level, the individual is likely to use dissonance-reducing heuristics, which will reduce the emotional concern particularly in the long term. These dissonance-reducing heuristics can cover up this way the influence of exposure on emotional concern. Exposure does not have a direct influence on risk perception. Another intervening variable between exposure and emotional concern is the emotional demarcation. Because females do have a lower emotional demarcation than men have, i.e. females are more empathic, they show higher levels of emotional concern even when they are not exposed on their own.

9. Zusammenfassung

Die Zielsetzung dieses Projektes war es, die psychologischen Prozesse, die der Risikowahrnehmung zugrunde liegen, auf einer individuellen Ebene zu analysieren. Dabei gab der Fall Dornach den angewandten Kontext. Dornach ist eine Gemeinde in der Nähe von Basel, in der grosse Teile des Bodens mit Schwermetallen kontaminiert sind. Da das persönliche Gesundheitsrisiko, welches von mit Schwermetallen belasteten Böden ausgeht, in hohem Masse von der Exposition abhängt, war die objektive Betroffenheit eine zentrale Variable in den Forschungsdesigns. Es wurden vier zeitlich aufeinander folgende Studien durchgeführt, so dass jeweils die Resultate der vorgängigen Studie in der Nachfolgenden Theorie generierend miteinbezogen werden konnten. Das Projekt hatte in sofern einen explorativen Charakter.

In der ersten quasi-experimentellen und Fragebogen basierten Studie (N= 80) wurde die Risikowahrnehmung von betroffenen Einwohnern von Dornach der Risikowahrnehmung von Personen aus vergleichbaren Orten gegenübergestellt, in denen es keine Bodenbelastung gab. Während erwartungsgemäss die betroffenen Personen das Risiko am Wohnort höher einschätzten als nicht selbst betroffene Personen, wurde das Risiko generell von betroffenen Leuten tiefer eingeschätzt. Das wahrgenommene Risiko von schwermetallbelasteten Böden wurde mit der Risikowahrnehmung anderer Risikoquellen verglichen und entsprechend einer Faktorenanalyse wird das Risiko von schwermetallbelasteten Böden im Vergleich indifferent hinsichtlich unmittelbaren Schrecken ('dread'), mittel hinsichtlich Unkontrollierbarkeit und gering hinsichtlich Katastrohpenpotential eingeschätzt. Nachhaltigkeitsgedanken wie z.B. der Schutz zukünftiger Generationen zeigten einen deutlichen Zusammenhang mit der Akzeptanz von Bioremediationsverfahren ('sanfte Sanierung'). Durch den intensiven Kontakt mit den Einwohnern von Dornach im Laufe dieser ersten Studie konnten wir einige weitere wichtige Einflussfaktoren auf die Risikowahrnehmung eruieren, wie z.B. der Gebrauch von Dissonanz reduzierenden Heuristiken oder die emotionale Betroffenheit als Gegenstück zur objektiven Betroffenheit. Diese zusätzlichen Variablen wurden in den folgenden Studien integriert.

In der zweiten Studie (N= 112) , ähnlich denen des Psychometrischen Paradigmas in der Risikoforschung, verglichen wir die Resultate aus einer 'klassischen' Faktorenanalyse, bei der über die Probanden aggregiert wird, mit einer 'individuellen' Faktorenanalyse, bei der über die Risikoquellen aggregiert wird. Das Risiko von schwermetallbelasteten Böden wurde einerseits mit anderen 'ultra-low-risks' wie dem Gebrauch von Mobiltelefonen, der Konsumation von Rindfleisch (BSE) und dem Verzehr von gentechnisch veränderten Lebensmitteln, sowie mit klassischen Risiken wie Rauchen, Strassenverkehr und Atomenergie verglichen. In der Faktorenanalyse auf der individuellen Ebene wurde der erste Faktor der klassischen Faktorenanalyse 'dread' in die zwei Komponenten emotionale Betroffenheit (1. Faktor) und Schadenspotential (2. Faktor) aufgeteilt. Nutzen war ein dritter Faktor. Regressionsanalysen zeigten, dass der Faktor der emotionalen Betroffenheit ein wichtiger Prädiktor für wahrgenommenes Risiko, Risikoakzeptanz und dem Wunsch nach mehr Information konstituiert. Während emotionale Betroffenheit und wahrgenommenes Schadenspotential signifikante Einflussgrössen für die Risikowahrnehmung darstellen, sind die besten Vorhersageparameter für die Risikoakzeptanz die emotionale Betroffenheit und der wahrgenommene Nutzen.

Die dritte quasi-experimentelle und Fragebogen basierten Studie (N= 57) wurde wieder in Dornach durchgeführt. Da die Höhe der Schwermetallbelastung in Dornach örtlich mit der Distanz zur ehemaligen Risikoquelle stark variiert, verglichen wir Personen aus am stärksten

belasteten mit Personen aus nur geringfügig belasteten Gebieten. Beide Gruppen schätzten das persönliche Risiko gleich ein. Die Gruppe der Nicht-Betroffenen schätzte aber das Risiko für andere Personen in Dornach deutlich höher ein. Neben diesen Effekt der objektiven Betroffenheit ist die Risikowahrnehmung an erster Stelle durch emotionale Betroffenheit determiniert. Das Ausmass des tatsächlichen Wissens über das Risiko hatte keinen Einfluss, die Selbsteinschätzung hinsichtlich des eigenen Wissenstandes hingegen schon. Das Bedürfnis nach einer Sanierung ist getrieben durch die Risikowahrnehmung, einer geringeren Anwendung von Dissonanz reduzierenden Heuristiken und einer Selbstverpflichtung zu Nachhaltigkeitsüberlegungen. Der Wunsch nach zusätzlicher Information zeigt keinen Zusammenhang zu tatsächlichem (fehlenden) Wissen sondern zur emotionalen Betroffenheit.

In der vierten Studie analysierten wir den Einfluss der von uns identifizierten Variablen mit einem experimentellen Computer basierten Untersuchungsdesign (N= 60). In dieser 'Mikrowelt' wurde der Fall Dornach modelliert. Den Versuchspersonen wurde entweder die Rolle als Nicht-Betroffener, als Betroffener oder als Experte zugeschrieben. Diese hatten verschieden Szenarios zu beurteilen, bei denen Schadensausmass und Eintretenswahrscheinlichkeit systematisch variiert wurden. Dabei integrierten die Versuchspersonen die Information zu Schadensausmass und Eintretenswahrscheinlichkeit nicht multiplikativ sondern additiv. Die objektive Betroffenheit hatte keinen direkten Einfluss auf die Risikoeinschätzungen, aber indirekt über die emotionale Betroffenheit. Emotional betroffene Personen hatten einen ausgeprägten Wunsch nach zusätzlicher Information, benutzten weniger Dissonanz reduzierende Heuristiken und waren eher im intuitiven Denkmodus. Der intuitive und der analytische Denkmodi hatten dabei unterschiedliche Effekte auf die Risikourteile.

Schliesslich wurde aufgrund der gewonnenen Erkenntnisse ein Modell zur individuellen Risikowahrnehmung entwickelt. Emotionale Betroffenheit spielt eine zentrale Rolle. Einerseits erhöht es das wahrgenommene Risiko direkt. Andererseits, wenn die emotionale Betroffenheit, wie Furcht oder Besorgnis, über einen individuellen akzeptierten Schwellwert zu liegen kommt, werden vermehrt Dissonanz reduzierende Heuristiken verwendet, welche die emotionale Betroffenheit wieder reduzieren. Diese Heuristiken können so insbesondere über einem langfristigen Zeitraum den Effekt der objektiven Betroffenheit auf die emotionale Betroffenheit überlagern. Emotionale Abgrenzung ist eine weitere Variable, welche den Einfluss der objektiven auf die emotionale Betroffenheit moderiert. Da Frauen sich generell weniger emotional abgrenzen als Männer, empathischer sind, zeigen diese eine emotionale Betroffenheit auch wenn sie selbst nicht objektiv betroffen sind.

10. Acknowledgements / Danksagung

Selbstverständlich bin ich Prof. Roland W. Scholz als betreuender Professor zu grossem Dank verpflichtet, sowie dem ganzen Team, das sich ebenfalls mit dem Fall Dornach befasste: Dr. Stefan Hesske, Dr. Olaf Tieje, Dr. Olaf Weber und den vielen anderen in diesem transdisziplinären Projekt und den Mitarbeitern der Professur für Umweltnatur- und Umweltsozialwissenschaften der ETH Zürich.

Ich bedanke mich herzlich bei Prof. Friedrich Wilkening der UNI Zürich, der als Korreferent die Idee des Functional Measurements beisteuerte.

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Ich danke den Gemeindevertretern von Dornach für die Mitgestaltung des ersten Fragebogens, sowie den Personen aus Dornach, welche hilfsbereit und interessiert bei den Befragungen teilgenommen haben.

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Zu guter letzt ist auch meiner Familie sowie Freunden, die mich ausserhalb des rein Sachlichen getragen haben, ein ganz besonderes Lob auszusprechen.

11. Appendix:

Integrale Bewertung von Sanierungsalternativen: Potentiale, Komponenten und Grenzen eines transdisziplinären Prozesses

OLAF TIETJE, ROLAND W. SCHOLZ, STEFAN HESSKE, OLAF WEBER, DIRK GRASMÜCK UND JAQUELINE FRICK (2002)

TERRA TECH, 2, 44-48

Zusammenfassung

Eine integrale Bewertung von Sanierungsalternativen umfasst ökonomische, soziale, rechtliche, technische, raum- und zeitbezogene und Umweltaspekte. Davon ausgehend, dass eine solche umfassende Beurteilung nur als gemeinsame Anstrengung der Beteiligten möglich ist, wurde die Vision verfolgt, mit der betroffenen Bevölkerung, mit den zuständigen lokalen und kantonalen Behörden, mit privatwirtschaftlichen Vertretern und den kollaborierenden Wissenschaftern aus dem Integrierten Projekt Boden des Schweizer Nationalfonds ein gemeinsames Nachhaltigkeitslernen zu organisieren. Dabei wurde ein transdisziplinäres Forschungsparadigma angewendet. Obwohl der so angestossene lokale transdisziplinäre Prozess als teilweise gescheitert angesehen werden muss, konnte eine Reihe von Forschungsergebnissen als angewandte interdisziplinäre Arbeit erreicht werden. Diese Ergebnisse beziehen sich auf drei Bereiche der Umweltentscheidungsforschung: Wahrnehmen (Untersuchung der Risikowahrnehmung in der Bevölkerung), Bewerten (Bewertungsmodell mit ökonomischen, ökologischen, und sozialen Kriterien), und Erlernen (transdisziplinäre Umweltbildung). Sie bauen auf den Ergebnissen der naturwissenschaftlichen Teilprojekte des IP Boden über die vorhandene Schwermetallbelastung und mögliche Sanierungsmethoden auf und stellen eine Grundlage für zukünftiges und gemeinsames Nachhaltigkeitslernen dar.

Einleitung

Die Lösung von komplexen Umweltproblemen, wie z.B. der Umgang mit Schadstoffen belasteten Böden, wie nationale/internationale Erfahrungen zeigen, bedarf es schon in den ersten Schritten der Problemlösung ein gemeinsames Vorgehen von zuständigen Behörden, betroffenen Bevölkerung, Wirtschaftsvertretern und Wissenschaftern. In diesem Prozess des Zusammenarbeitens werden nicht nur fachliche, z.B. bodenkundliche oder umwelttoxikologische Grundlagen werden benötigt. Wichtig ist es in diesem Prozess den Sachstand und die relevanten Auswirkungen für die Beteiligten einschliesslich der bestehenden wissenschaftlichen Unsicherheiten angemessen diskutieren. Wünschenswert ist hier ein transdisziplinärer Ansatz (Thompson Klein et al., 2001) der integralen Bewertung von Bodensanierungsmassnahmen (Scholz et al., 1997). Wesentlicher Bestandteil dieses Prozesses unter einer integralen Bewertung sind die Risikowahrnehmung der Betroffenen sowie der ökonomischen Auswirkungen von Bodenreinigungen. Wir stellen in diesem Artikel Ergebnisse aus verschiedenen Projekten, eine Schnittstelle zwischen Umweltnatur- und Umweltsozialwissenschaften, vor, welche die

- Risikowahrnehmung der Betroffenen
- die finanzwirtschaftlichen Auswirkungen von Bodensanierungen
- den Umgang mit Unsicherheiten in einem Consensus und Sicherheiten über die Wirksamkeit von Wohnsanierungsmassnahmen in einem Consensus-Bildungsprozess zwischen Experten und
- die Ergebnisse einer integralen Bewertung vor, welche unter Wissenschaftlern durchgeführt worden ist.

Es ist anzumerken, dass die ursprüngliche Intention des integrierten Projekt des Bodens diese Ergebnisse in einem partizipativen Prozess in der Gemeinde Dornach zu nutzen nicht erreicht werden konnte. Wir werden auf diesen Punkt in der Schlussdiskussion nochmals eingehen. Die Schwierigkeiten eines abgeklärten und rationalen Diskurses über Bodenrisiken, wie sie in einmaliger Form am Fallbeispiel Dornach erleben durften, zeigt, dass im Bereich Risikowahrnehmung und Risikokommunikation elementare Defizite bestehen. Es dürfte sich auch als Illusion erweisen; aktuelle Informationskampagnen diese grundsätzlichen Probleme der Risikowahrnehmung zu überkommen. Aus diesem Grund berichten wir über ein transdisziplinäres Projekt zu Bodenrisiken, welches am diskutierten Fallbeispiel in Schweizer Gymnasien durchgeführt worden ist.

Das wissenschaftliche Ziel des praktischen Umgangs mit den vorliegenden Schwermetallbelastungen besteht darin, die gesellschaftliche Perspektive der Nachhaltigkeit mit den individuellen Bewertungen der beteiligten Akteure zu verbinden. Um dieses Ziel zu erreichen unterscheiden wir zwei Extremperspektiven. Eine expertenbasierte Nachhaltigkeits-bewertung auf der einen Seite steht einer akteursbezogenen Realbewertung auf der anderen Seite gegenüber (siehe Abbildung 1).

Transdisziplinärer Prozess *Integrale Bewertung*

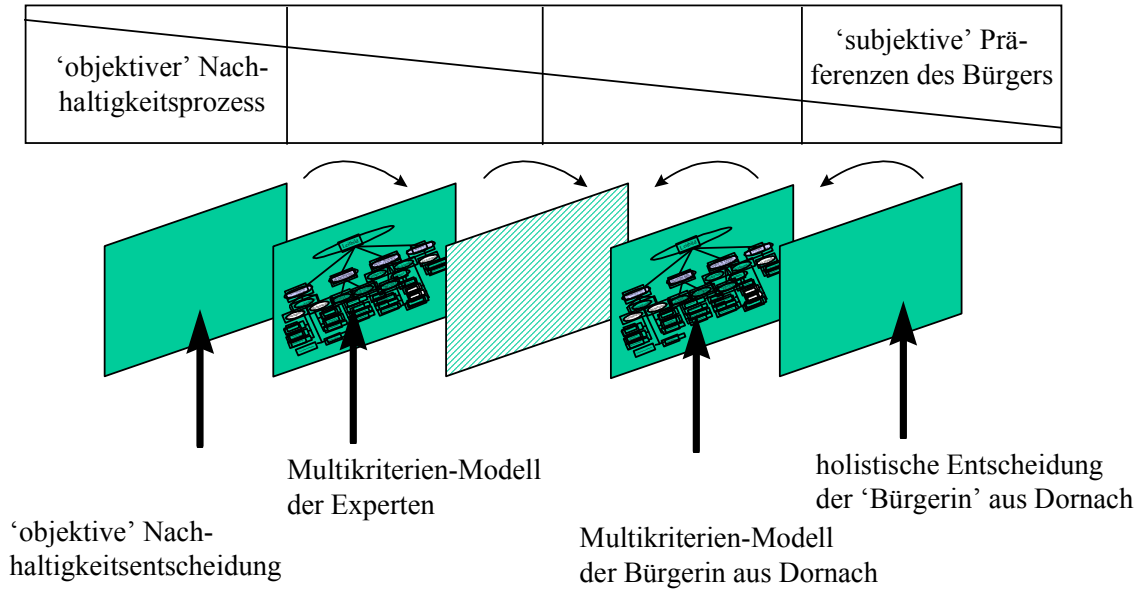

Abb 1: zwei Extremperspektiven. Eine expertenbasierte Nachhaltigkeitsbewertung auf der einen Seite steht einer akteursbezogenen Realbewertung auf der anderen Seite gegenüber (siehe Abbildung 1).

Wahrnehmen – Bewerten – Erlernen

Grundlagen

Eine determinierte, direkt messbare Schädigung der menschlichen Gesundheit durch Schwermetalle im Boden – in den in Dornach vorkommenden Konzentrationen – existiert nicht. Dass eine Gefährdung vorliegt, ist jedoch unbestritten. Ob daraus auch ein Schaden folgt, kann nicht mit Sicherheit gesagt werden. Das Risiko, das sich aus der Gefährdung ergibt, muss daher bei der Beurteilung der Belastung und allfälliger Sanierungsverfahren eine zentrale Stellung einnehmen. Im Sinne des dargestellten transdisziplinären Forschungsansatzes besteht das Risiko aber nicht (nur) in der Unsicherheit der von den Experten vorhergesagten Schäden. Vielmehr ist „Risiko“ ein *Konstrukt*, das bei der Beurteilung der Schwermetallbelstung durch die Beteiligten aktiviert wird. Nach unserem Ansatz gibt es also auf der einen Seite eine von den Experten erwartete Gefährdung durch Schwermetalle im Boden. Das Ausmass dieser Gefährdung und dessen Unsicherheit wird oft unter dem Begriff „Risiko“ versucht zu quantifizieren (z. B. Geiger & Schulin 1995). Auf der anderen Seite besitzt jeder der Beteiligten einen eigenen, subjektiven Begriff von Risiko, den er für die Beurteilung des eigenen Handelns heranzieht. Will man also als zuständige Behörde oder als Wissenschaftler eine in der Bevölkerung akzeptierte Sanierung unterstützen, muss man die *Risiken* (im Sinne von: die Risikokonstrukte) kennen, die die EinwohnerInnen wahrnehmen – etwas lax ausgedrückt: die sich die EinwohnerInnen vorstellen. Das kann natürlich im Einzelfall eine „naive“ (oder „unwissenschaftliche“) Risikovorstellung sein, kann aber auch (wie in den meisten Fällen) ein durch persönliche Erfahrung gewachsenes,

mit Fakten begründetes und überlegtes Konstrukt sein. Wie auch immer man dies von aussen beurteilen möchte – letztendlich wissen kann es nur der Betroffene selbst. Die Forschung über Entscheidungen unter Unsicherheit hat verschiedene Modelle vorgestellt, unter welchen Bedingungen ein solches Risiko wahrgenommen wird, von welchen Faktoren es beeinflusst wird und wie es schematisch dargestellt wird (Fishburn 1984, Vlek und Stallen 1981, Yates und Stone 1992). Scholz & Tietje (2002, Seite 180f) haben basierend darauf eine „Allgemeine Risikofunktion“ definiert, in der die psychologisch und entscheidungsrelevanten Elemente mit den naturwissenschaftlich quantifizierbaren Risikoaspekten verbunden werden. Sie ist Teil des Risikohandlungsmodells (Scholz et al., 1997), das bereits in unserem früheren Terratech-Beitrag erläutert wurde (Scholz et al., 1999). Diese Risikofunktion ist der Gegenstand unserer Untersuchungen. Im nächsten Abschnitt (Wahrnehmen) wird der vorliegende *Raum der Risikokognitionen* eingegrenzt. Der darauf folgenden Abschnitt beschäftigt sich mit den Kriterien (Values), von denen allgemein angenommen wird, dass sie die Risikowahrnehmung beeinflussen. Der letzte Teil des Kapitels untersucht eine Möglichkeit, wie in der Umweltbildung langfristige Risiken vermittelt werden können.

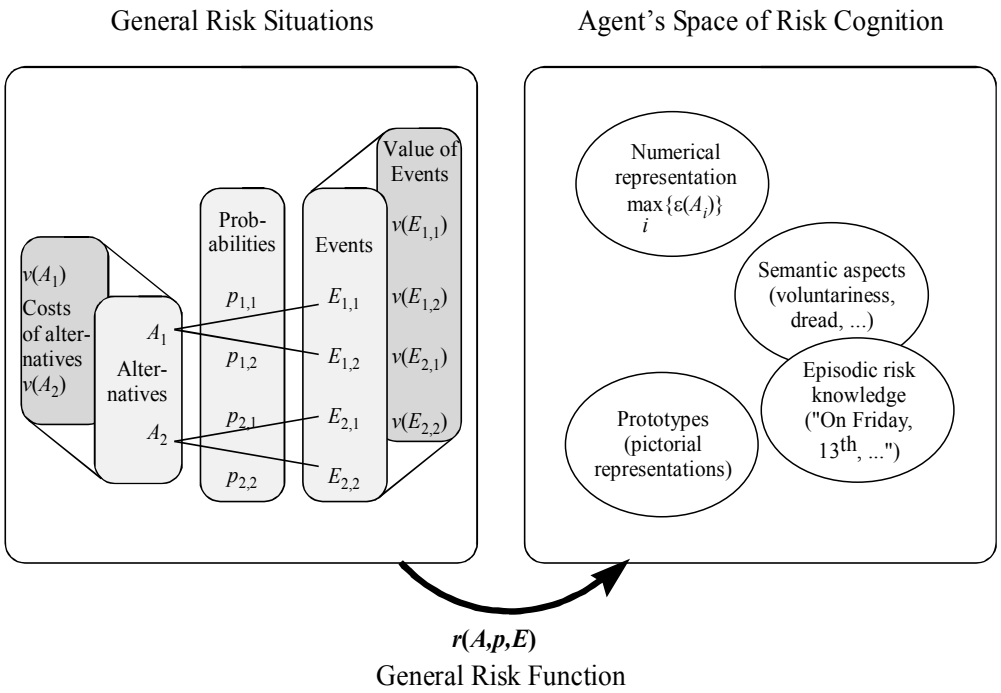

Abb. 2: Allgemeine Risikofunktion.

Wahrnehmen: Bewertungen durch die Bevölkerung von Dornach

Bei einem transdisziplinären Vorgehen sollten auch die Betroffenen in den Beurteilungs- und Entscheidungsfindungsprozess einbezogen werden, um eine sozial akzeptierte und nachhaltige Lösung herbeizuführen (Covello & Allen, 1988). Dabei ist zu berücksichtigen, dass Laien Risiken anders als Experten beurteilen. Während Experten sich eher an quantifizierbaren Indikatoren wie Schadenspotential und Eintretenswahrscheinlichkeit orientieren, spielen bei der Risikowahrnehmung von Laien vor allem qualitative Aspekte eine bedeutende Rolle.
So zeigen erste Resultate einer Untersuchung, bei welcher wir Versuchspersonen innerhalb einer Computerumgebung verschiedene systematisch variierte Szenarios zu Schwermetallbelastung beurteilen liessen, dass diese die beiden Komponenten Schadensausmass und Eintretenswahrscheinlichkeit kaum multiplikativ verknüpfen, sondern eher additiv oder sie zentrieren auf eine Komponente, in der Regel auf den maximal möglichen Schaden und dies in Abhängigkeit zur emotional verspürten Betroffenheit (Grasmück, Hürlimann & Scholz, 2001).
Neben diesen "quantitativen", resp. potenziell quantifizierbaren Aspekten von Schadensausmass und Wahrscheinlichkeit sind es aber eben hauptsächlich "qualitative Aspekte", welche das Laienurteil beeinflussen. So konnte Slovic (1987) im sogenannten "psychometrischen Paradigma" der Risikowahrnehmungsforschung aufzeigen, dass die subjektive Einschätzung von Aspekten wie Freiwilligkeit, Vertrautheit, Kontrollierbarkeit, Katastrophenpotenzial, gerechte Verteilung von Nutzen, etc. die Risikowahrnehmung und die Akzeptanz von Risikoquellen bei Laien beeinflussen. Eine Risikoquelle wird demnach weniger akzeptiert, wenn man ihr unfreiwillig ausgesetzt ist, sie weniger vertraut ist, sie als unkontrollierbar erscheint, sie eine mögliche Katastrophe in sich birgt, sowie ein allfälliger Nutzen ungerecht verteilt ist.
Bei einer Befragung, bei der 40 Personen in Dornach und 40 Personen einer Kontrollgruppe teilnahmen, und die wir vor Ort durchführten (Weber, Scholz, Bühlmann, & Grasmück, (2001), liessen wir unter anderem die Risikosemantik von schwermetallbelasteten Böden bestimmen. Dabei konnten die drei Faktoren Unbehaglichkeit, Kontrolle und Merklichkeit (des Katastrophenpotenzials) bestätigt werden. Schwermetallbelastete Böden wurden im Vergleich zu anderen Risikoquellen als eher unkontrollierbar (0.43; Gentechnik: 0.81; Tabakgenuss: -1.3) und kaum merklich eingeschätzt (-0.31; Atomkraft: 1.28; Tabakgenuss: -0.55). Hinsichtlich der Unbehaglichkeit ergab sich eine indifferente Faktorenladung von 0,08 (Ozonloch: 0.79; Konservierungsstoffe: -0.63).
Bei den Fragen, inwieweit eine Sanierung als notwendig und eine sanfte Sanierung als sinnvoll erachtet wird, zeigte sich, dass Nachhaltigkeitsüberlegungen bei der Beurteilung eine bedeutende Rolle spielen (siehe Grafik 3). Personen, welche bei schwermetallbelasteten Böden ein höheres Risiko für zukünftige Generationen sahen, beurteilten eine sanfte Sanierung auch als sinnvoller (r=.43**).
Auch mussten die Befragten zwei Varianten der Phytoremediation mit dem Abtragen von Bodenmaterial vergleichen. Dabei war die Akzeptanz für ein sanftes Verfahren recht gross. Eine Phytoremediation wurde hinsichtlich der ökologischen Verträglichkeit und der Kosten-Nutzen-Relation besser als das Abtragen des Bodenmaterials eingeschätzt. Das ästhetische Erscheinungsbild wurde für beide der vorgestellten Varianten "Tabak" und "Weiden" als positiv beurteilt. Das Abtragen von Boden wurde als wirksamer betrachtet. Bei der Frage nach der Wichtigkeit erhielten alle Aspekte auf einer Skala von 1 (= unwichtig) bis 7 (= sehr wichtig) einen durchschnittlichen Wert über 5.
Bei der Phytoremediation dürfte die Sanierung gemäss Angaben der Dornacher eine maximale Dauer von 6.8 Jahre nicht überschreiten (Durchschnittswert). Allerdings je näher die Befragten

an der Emmissionsquelle wohnhaft sind, je länger sie bereits in Dornach wohnen und je mehr Land sie besitzen, desto weniger wird eine Sanierung als notwendig erachtet und, falls doch eine Sanierung durchgeführt würde, desto kürzer müsste die Sanierungsdauer dann sein.

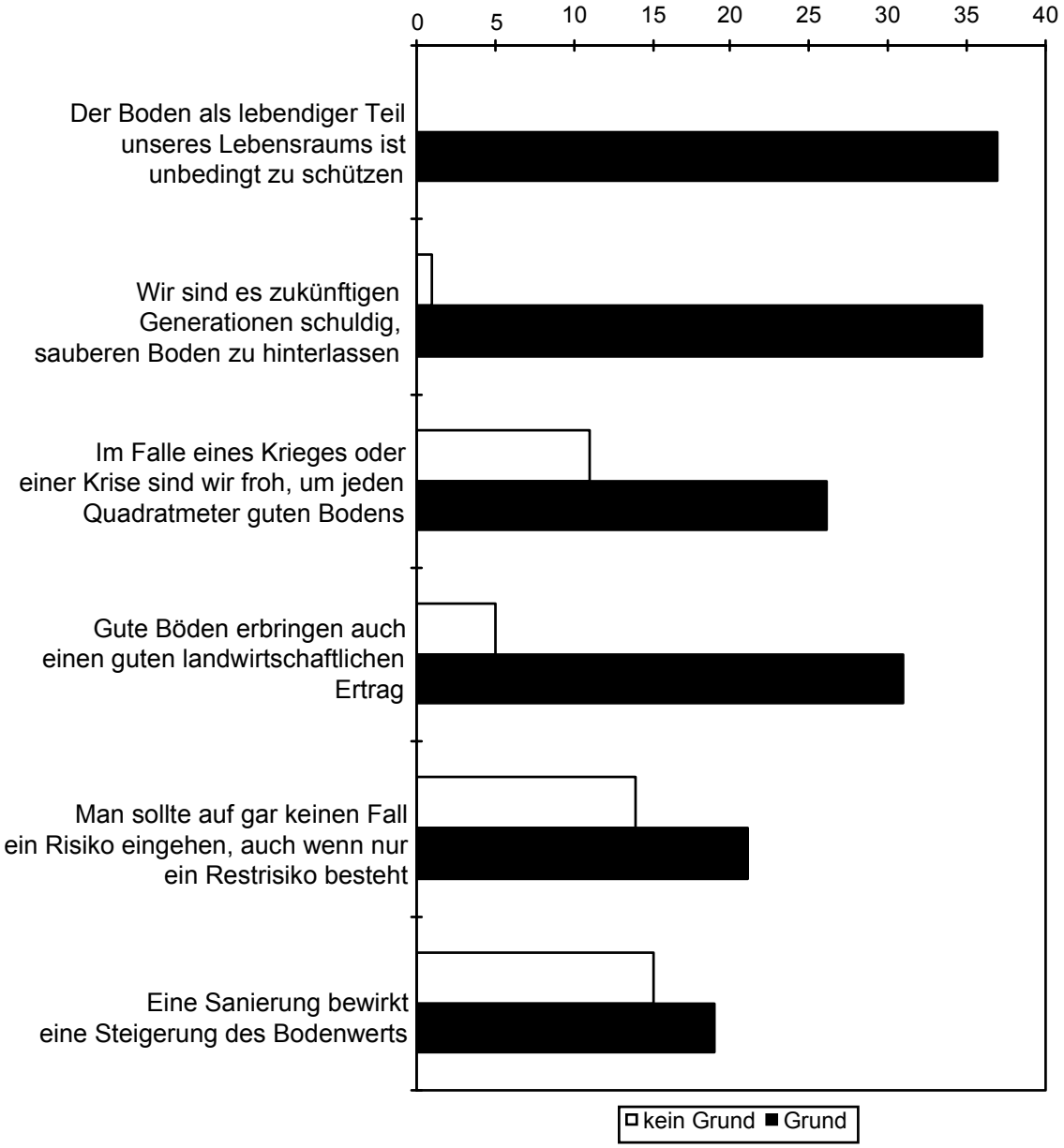

Abbildung 3: *Die Beurteilung von sanfter Sanierung durch die Dornacher Befragten. Antworten auf die Frage: „Warum halten Sie eine sanfte Sanierung generell für sinnvoll?“. Die Antwortmöglichkeiten wurden vorgegeben. (n=37, 3 Personen hielten eine (sanfte) Sanierung in keiner Weise als sinnvoll oder notwendig.)*

Bewerten: Kriterien für Sanierungsalternativen

Wirkgrössen und Belastungsvorstellung

Um die Belastungsvorstellung zu erfassen, müssen die relevanten Wirkgrössen identifiziert werden und einem einfachen Systemmodell (Umweltmodell) zugeordnet werden können. Das Systemmodell besteht aus zwei Teilsystemen, der Landnutzung und den Stoffflüssen im Boden. Die Sanierungsalternativen und ihre Eigenschaften (Dauer der Sanierung, Kosten, Verkaufswert des Grundstücks, Nutzungseinschränkungen, Umweltauswirkungen (Ökobilanz des Verfahrens), gesundheitliche Gefährdung u.a.) gehören zum Landnutzungsmodell. Sie werden direkt durch die Wahl des Sanierungsverfahrens beeinflusst. Die Schadstoffbilanz im Boden und insbesondere die Schadstoffreduktion durch sanfte Sanierungsverfahren werden – neben der Wahl des Sanierungsverfahrens - durch die Bodeneigenschaften und die im Boden ablaufenden Prozesse bestimmt (insbesondere Schadstoffkonzentration, pH-Wert, Kalkgehalt und Pflanzenaufnahme, Löslichkeit). Die genaue Quantifizierung dieser Materialflüsse ist für eine einzelne Parzelle zu aufwendig. Die naturwissenschaftlichen Untersuchungen hatten insbesondere das Ziel, die Unsicherheiten bei der Abschätzung dieser Materialflüsse zu reduzieren und verlässliche Aussagen über die Dauer einer sanften Sanierung und die erzielbare Schadstoffreduktion zu machen. Für die Bewertung der Sanierungsalternativen sind die Einschätzungen der erwarteten Stoffflüsse und deren Unsicherheiten essentiell. Daher wurden im Projekt ‚Konsens Technologische Leistungsfähigkeit' Expertenschätzungen für die Wirkgrössen und entsprechende Folgerungen für die Sanierungsalternativen zusammengefasst.

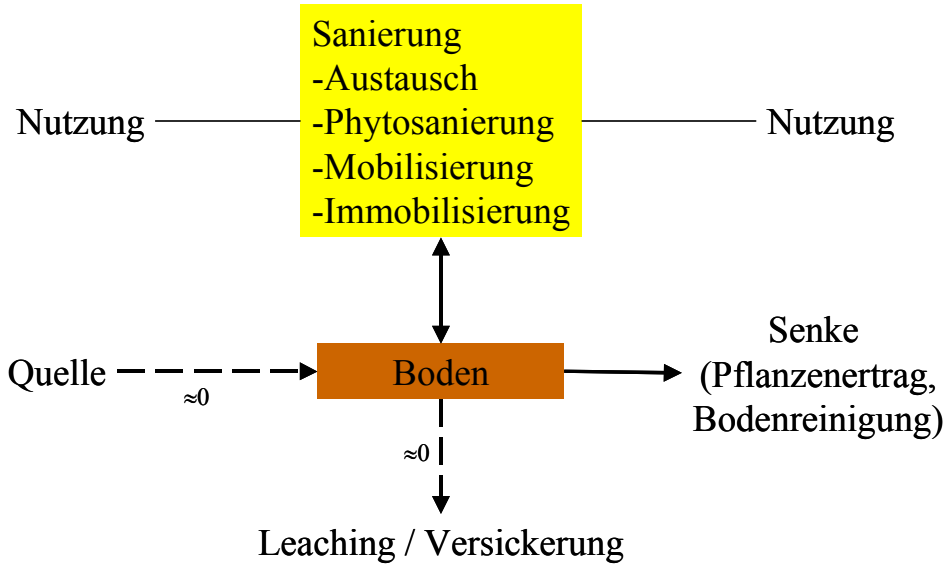

Abbildung 4: Systemmodell

Bewertungskriterien

Das Bewertungsmodell versucht, einen Sanierungsverantwortlichen in seiner individuellen Entscheidung zu unterstützen. Die Bewertungskriterien wurden subsummiert unter den drei Hauptkriterien Ökologie, Wirtschaftlichkeit und Sozialverträglichkeit (Scholz et al., 1999).
Ökologische Kriterien sind:

- die Bodenfruchtbarkeit (Bodenqualität),
- nachhaltige Stoffflüsse (hier wird berücksichtigt, ob, welche Menge und in welcher Form Schadstoffe im Boden verbleiben),
- Umweltauswirkungen (Ökobilanz), und
- Ökoeffizienz (vgl. dazu Scholz et al., 1999).

Wirtschaftliche Kriterien sind

- die direkten Kosten des Sanierungsverfahrens (für sanfte Sanierungsverfahren die Gesamtkosten während der mehrjährigen Dauer, diskontiert als gegenwärtige Kosten),
- die Opportunitätskosten (gemessen als der Verlust, der durch die Verzögerung des Verkaufs eines Grundstücks durch eine anhaltende Sanierung entstehen würde) und
- Belehnungswertkorrekturen (siehe Kasten).

Da eine individuelle Bewertungsperspektive (zum Beispiel eines privaten Eigentümers) eingenommen wird, erfolgt die Bewertung der sozialen Verträglichkeit mit den Kriterien

- gesundheitliches Risiko (in Abhängigkeit von der Nutzung und dem Schwermetallgehalt),
- Nutzungsbeeinträchtigungen (hierzu gehören zum Beispiel: rechtliche Nutzungs-einschränkungen, die Dauer des Verfahrens, Beeinträchtigungen durch Baumassnahmen wie Bodenabtrag oder durch das Anpflanzen von durch das Sanierungsverfahren vorgeschriebene Pflanzen in Hausgärten) und
- die Erprobtheit des Verfahrens (ob zum Beispiel Erfahrungen aus vielfältigen Anwendungen vorliegen, oder ob es sich eher um prototypische Anwendungen handelt).

Diese Bewertungskriterien werden mit Hilfe einer Multikriterienbewertung der Sanierungsalternativen zusammengefasst (s. Abb xx).

Bewertungsmodell *Administration / Experten*

Das dargestellte Bewertungsmodell stellt den Rahmen für eine expertenunterstützte individuelle Bewertung dar. Im Einzelfall sind hier sowohl die Gewichtungen der Kriterien zu ergänzen als auch Änderungen an den Kriterien zuzulassen.

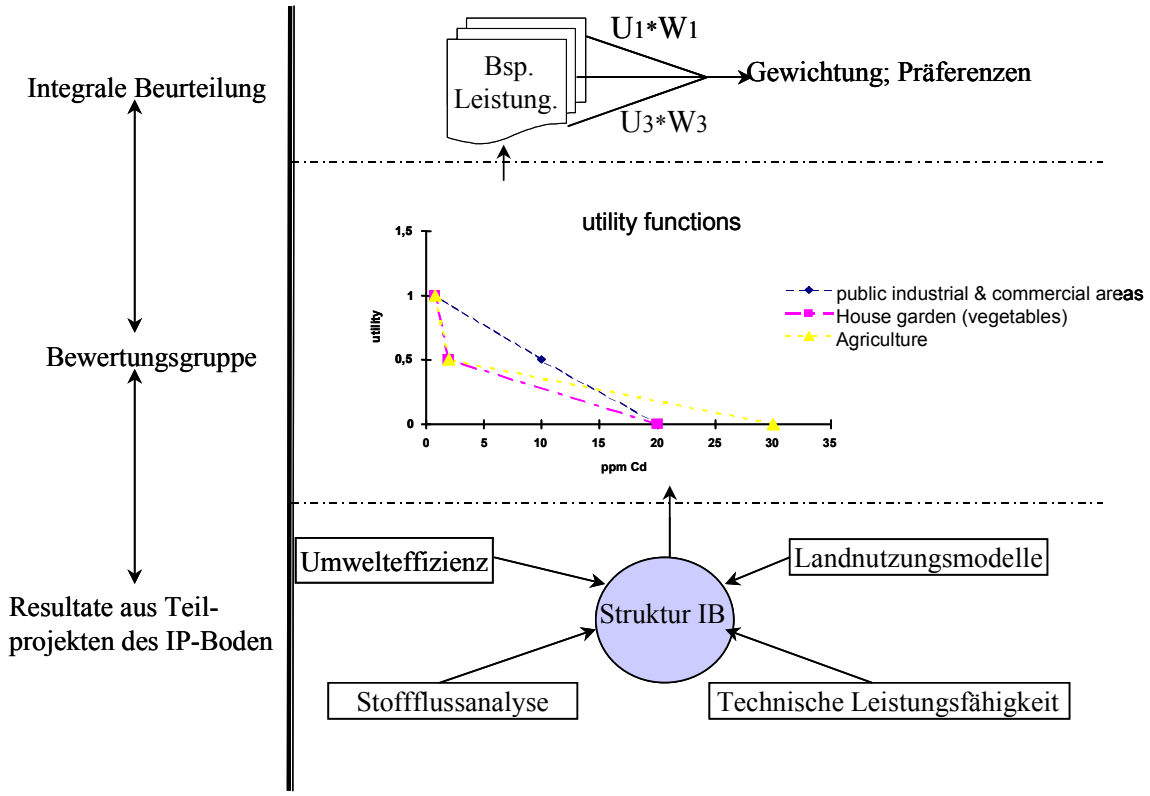

Abb 5: Schema der Multikriterienbewertung.

Erlernen: Transdisziplinäre Umweltbildung 2001 (TDU) – Pilotstudie "Risiko & Boden"

Da wir jahrzehntelange Bodenbelastungen heute nicht sofort beheben können und wir mit fruchtbarem Boden nachhaltig umgehen sollten, müssen wir auch Jugendliche als Entscheidungsträger von morgen in den langfristigen Lösungsprozess mit einbeziehen. So wurde im Rahmen des IP Boden ein Konzept für eine transdisziplinäre Umweltbildung (TDU) entwickelt (Hesske & Frischknecht-Tobler 1999, 2000). Es kombiniert fächerübergreifenden Unterricht mit Fallstudienmethode, projektartigem Unterricht und entdeckendem Lernen. Die Erprobung erfolgte an dem konkreten Fallbeispiel der Gemeinde Dornach, wo eine Gymnasialklasse der Kantonsschule Sargans die komplexe Umweltproblematik einer Bodenbelastung durch Schwermetalle nicht nur zusammen mit Akteuren praxisorientiert und ganzheitlich vermittelt erhielt, sondern auch aktiv am Problemlöseverfahren beteiligt wurden.

Ernüchtert stellten die Jugendlichen fest, dass sich viele Betroffene an die Bodenbelastung gewöhnt haben und kaum etwas dagegen unternehmen. - Die Evaluation dieser Pilotstudie in Form eines experimentellen Designs mit zwei Kontrollklassen (siehe Graphik) ergab, dass sowohl TDU als auch herkömmlicher Unterricht zum Thema Boden eine signifikante Erhöhung des Fachwissens zum Thema Boden und des allgemeinen Umweltwissens zur Folge hat, im Gegensatz zur Klasse ohne Bodenunterricht. Dieser Zuwachs ist auch drei Monate nach Intervention noch feststellbar. Zusätzlich erwies sich, dass in der Gruppe mit TDU, im Gegensatz zur Gruppe mit normalem Bodenunterricht, ebenfalls das allgemeine Umweltverhalten signifikant anstieg.

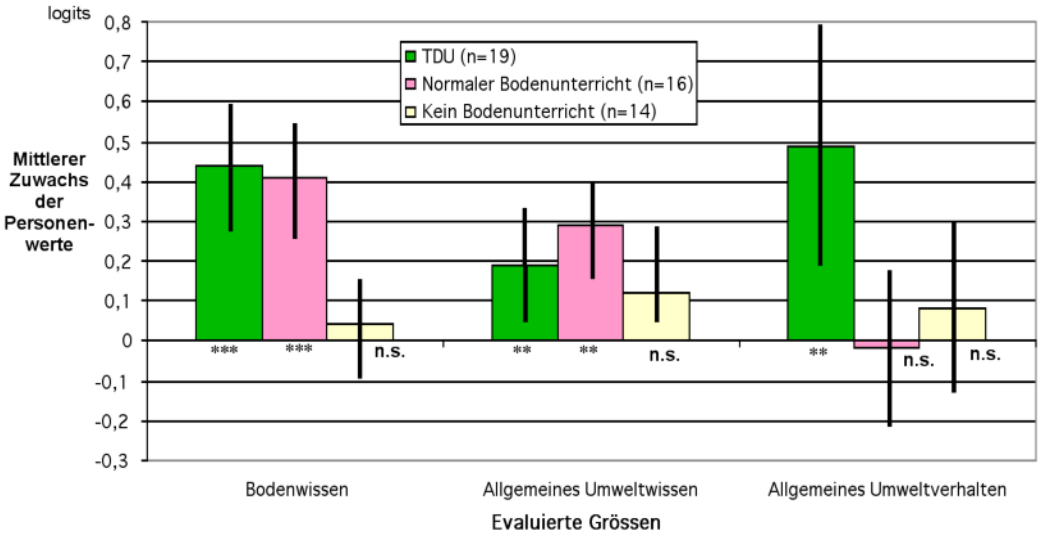

Abb. 6: Wirksamkeit der TDU und zweier Arten von Vergleichsunterricht gemessen am Zuwachs von spezifischem Bodenwissen sowie allgemeinem Umweltwissen und Umweltverhalten zwischen März (vor der Intervention) und September 2001 (drei Monate nach Intervention). Angabe der Personenmittelwerte in logarithmierten Wahrscheinlichkeiten (logits), Signifikanz des Zuwachses in jeder Gruppe: **: p < .01; ***: p < .001; n.s.: nicht signifikant. Vertikale Linien bezeichnen 90%-Vertrauensintervalle: nicht überlappende Linien weisen auf bedeutsame Gruppenunterschiede hin.

Diskussion und Schlussfolgerungen

Wir haben gezeigt, in welcher Weise im Bereich der Problemlösung des Zusammenspiels zwischen Natur- und Sozialwissenschaften gefordert ist. Von noch grösserer Bedeutung erscheint uns jedoch retrospektiv die Gestaltung von transdisziplinären, d.h., partizipativen, die Theorie und die Praxis gleichermassen einbeziehenden Problemlösungsprozessen.
Wie eingangs angedeutet, konnte ein solcher Prozess in der Gemeinde Dornach nicht realisiert werden. Grosse Ängste und Verengungen in der Risikowahrnehmung (vgl. Grasmück et al. 2001) haben vermutlich ihre Gründung in der Furcht vor Einbussen im Standortimage und im Wertverlust von Grundstücken. Diese - an andern Orten nicht vorzufindende - Zurückhaltung, lässt sich nahezu 15 Jahre zurückverfolgen. Es wurden anfänglich Risikoinformation der Bevölkerung durch die Bodenbelastung zurückgehalten oder verharmlost bis eine alarmierende Boden- und Pflanzenuntersuchung (Wirz & Winistörfer, 1987) und Gerüchte über die schlechte Bodenqualität die Wohnbevölkerung verunsicherten und zu verstimmen begannen.
Bemerkenswert ist auch, das nahezu 15 Jahre vergangen sind, bis von Seiten der übergeordneten Kantonalen und Bundesbehörden klare Vorschriften kommuniziert wurden. Grundlage für diesen Vollzug war die Revision des USG und die revidierte Verordnung über die Belastungen des Bodens VBBo (1998 in Kraft getreten). Aber auch diese Grundlagen konnten eine Reihe von Dilemmata, welche in Schwierigkeit der Belastungsfeststellung und damit verbunden der Sanierungsbedarfs nicht hinreichend klären. Hinzu kam, dass durch den intransparenten und weitgehend hinter verschlossenen Türen stattfindenden Verhandlungsprozess mit dem Verursacher und durch Änderung der Ämterstruktur im Kanton weitere Verzögerungen und Leerräume entstanden.
Die Möglichkeiten einer integralen Bewertung, wie sie im vorliegenden Papier dargestellt wurden, konnten somit am Fall Dornach keine praktische Wirkung zeitigen. Dennoch konnte eine gewisse Klärung erreicht werden, da die lange Zeit diskutierte Sanierungsvariante der Phytosanierung wegen der von der Bevölkerung nicht akzeptierten Sanierungsdauer (>20 Jahre) nicht in Frage kam (siehe Scholz et al., 1999). Im Zusammenspiel mit den grossen Unsicherheiten über die Bodenbelastungen und der noch offen stehenden Frage, wie das Verursacherprinzip zu interpretieren ist, lässt erwarten, dass es auch im vorliegenden Fall Dornach auch mittelfristig keine flächendeckende befriedigende Lösung des Bodenbelastungsproblems geben wird.

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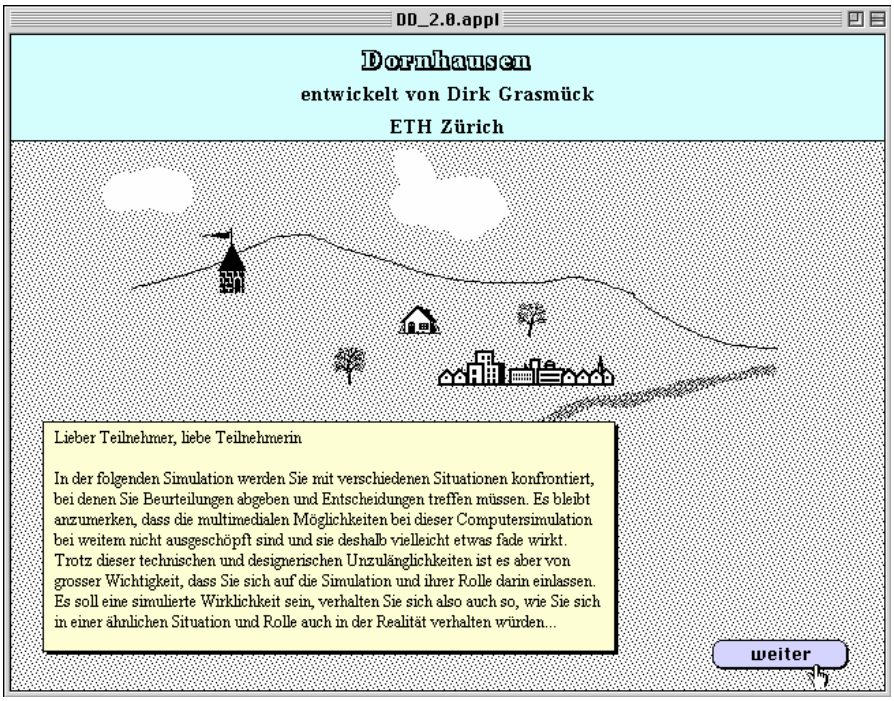
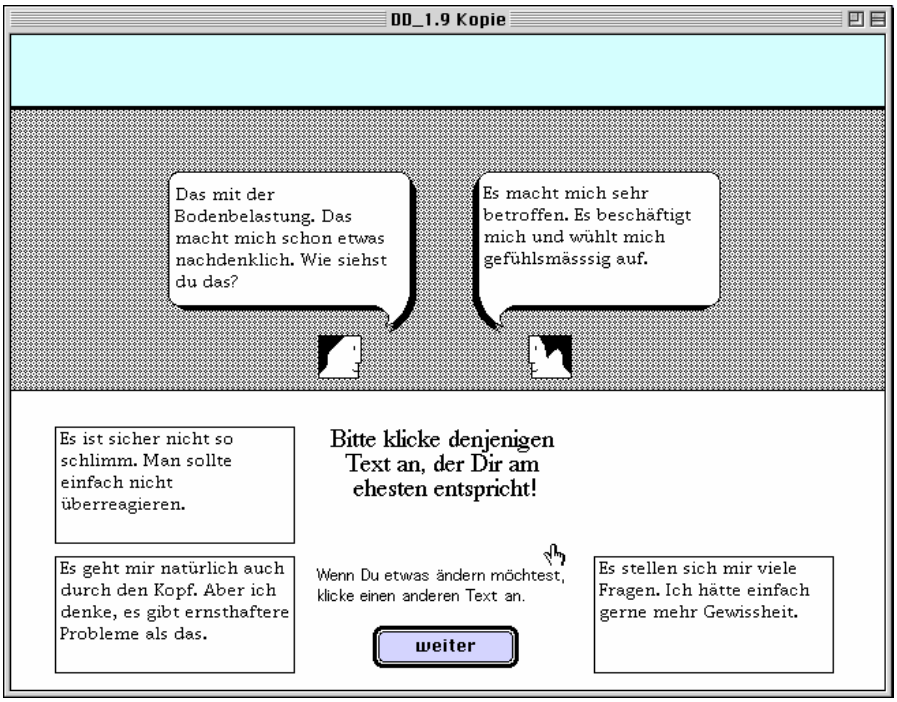
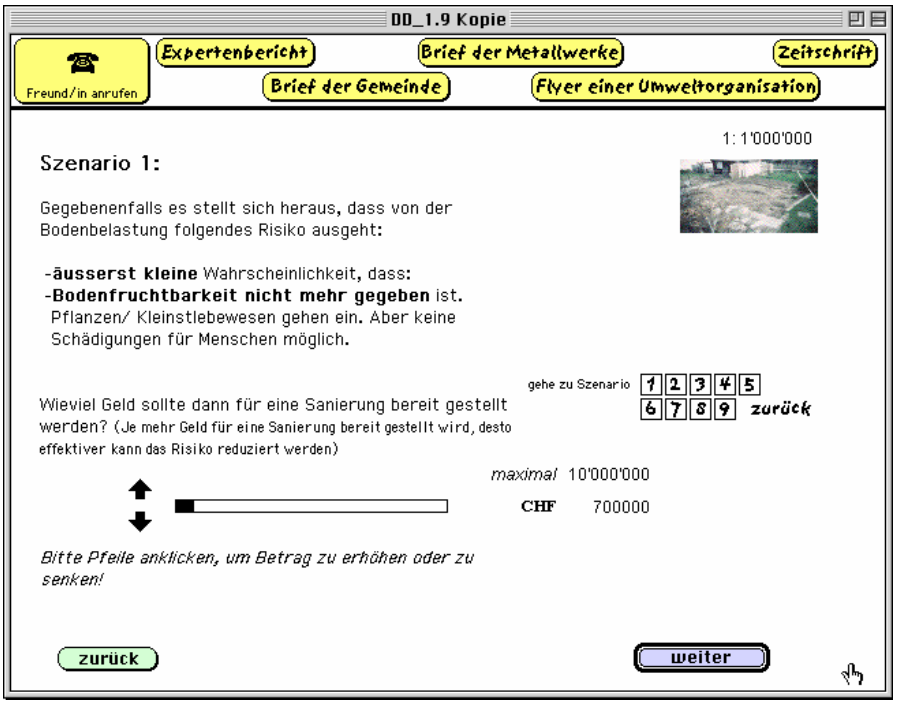
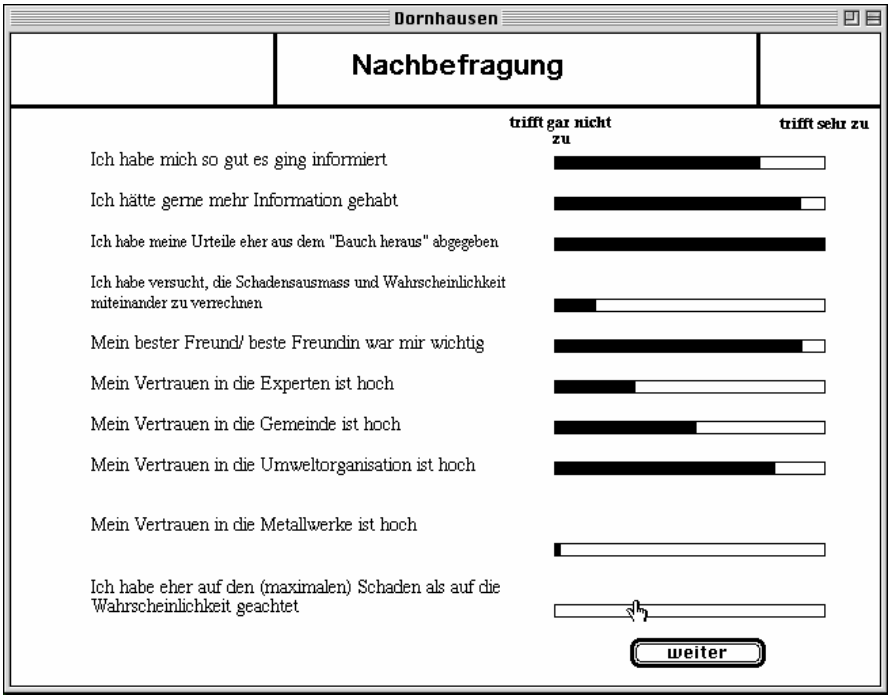
Appendix 2: Screenshots of the Microworld 'Dornhausen'






DD_1.9 Kopie
Freund/in anrufen
Expertenbericht
Brief der Metallwerke
Zeitschrift
Brief der Gemeinde
Flyer einer Umweltorganisation
1: 1'000'000
Szenario 1:
Gegebenenfalls es stellt sich heraus, dass von der Bodenbelastung folgendes Risiko ausgeht:
-äusserst kleine Wahrscheinlichkeit, dass:
-Bodenfruchtbarkeit nicht mehr gegeben ist.
Pflanzen/ Kleinstlebewesen gehen ein. Aber keine Schädigungen für Menschen möglich.
gehe zu Szenario 1 2 3 4 5 6 7 8 9 zurück
Wieviel Geld sollte dann für eine Sanierung bereit gestellt werden? (Je mehr Geld für eine Sanierung bereit gestellt wird, desto effektiver kann das Risiko reduziert werden)
maximal 10'000'000
CHF 700000
Bitte Pfeile anklicken, um Betrag zu erhöhen oder zu senken!
zurück
weiter


Dornhausen
Nachbefragung
trifft gar nicht zu
trifft sehr zu
Ich habe mich so gut es ging informiert
Ich hätte gerne mehr Information gehabt
Ich habe meine Urteile eher aus dem "Bauch heraus" abgegeben
Ich habe versucht, die Schadensausmass und Wahrscheinlichkeit miteinander zu verrechnen
Mein bester Freund/ beste Freundin war mir wichtig
Mein Vertrauen in die Experten ist hoch
Mein Vertrauen in die Gemeinde ist hoch
Mein Vertrauen in die Umweltorganisation ist hoch
Mein Vertrauen in die Metallwerke ist hoch
Ich habe eher auf den (maximalen) Schaden als auf die Wahrscheinlichkeit geachtet
weiter

12. Curriculum Vitae / Lebenslauf

Name	Grasmück
Vorname	Dirk
Geburtsdatum	08.09.1968
Geburtsort	Offenbach, Deutschland

1984-1989	**Kantonsschule Pfäffikon, SZ** Matura Typus E (Wirtschaft)
1990-1992	**UBS AG, Zürich** Bankpraktikum
1992-1999	**Universität Zürich** Abschluss: lic. phil. Hauptfach: Psychologie, mit Vertiefung in Allgemeiner Psychologie biologisch-mathematischer Richtung bei Prof. Norbert Bischof. Nebenfächer: Soziologie und Neurophysiologie Lizentiatsarbeit: "Entwicklung eines computergestützten Fragebogens zur Erhebung von Motivkennwerten".
2000-2004	**ETH Zürich** Mitarbeiter und Doktorand am Institut für Human and Environmental Systems (HES), in der Abteilung Natural and Social Science Interface (NSSI) bei Prof. Roland W. Scholz.